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FIRST MENSTRUATION AND SUBSEQUENT MENSTRUAL CYCLES OF PUBERTAL GIRLS

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MANY facts relating to the endocrine factors in puberty and to the endocrine relationships of the menstrual cycle have been elicited during the past few years. There has been, however, no norm of menstrual performance for the pubertal girl. The present contribution offers some data on this point, and indicates the need for more extensive studies in the same field.

SOURCE AND NATURE OF DATA

The present study of the first menstruation and of subsequent menstrual cycles was made possible by the data on record in the Hebrew Orphan Asylum of New York City. The records were made accessible through the interest and courtesy of the executive director, Dr. L. J. Simmonds.[1]

Records of individuals, which the institution has on file, contributed the following pertinent data: The date and place of birth of each person; an individual medical record with a pre-institutional case-history and yearly examination reports during residence, and a complete menstrual

[1] The authors wish to thank Dr. Raymond Franzen for assistance with the statistical treatment of these data. The formulae cited below were also suggested by Dr. Franzen.

record of each girl. A study of the appearance of the first menstruation (menarche) necessitated an accurate statement of the birth date, the date of onset of the first menstrual period, and, for purposes discussed below, the date of admission to the institution. Accurate records of birth were obtainable for only a portion of the cases. In some instances, on the various papers kept with the child's history as many as four different birth dates, with as great a difference as two years, have been registered. To insure accuracy, all cases which had no birth certificates attached or no similarly authentic records were excluded from these studies.

As part of the routine of the institution, girls from the age of ten are given special and individual instruction in sex hygiene. All girls are required to report to the matron or designated assistant at the onset of each menstrual period for sanitary napkins, and a record is made thereof on cards designed for that purpose. In view of the preliminary instructions it is believed that few, if any, first menstruations are concealed and that these records represent accurate conditions. After the first menstruation the records are inspected every month by the assistant in charge. Any child who has not reported during that month is questioned by the nurse. If a second month elapses without a period, the child is referred to the physician in charge. Note of any abnormality, if any, is recorded in the medical history. The record is maintained continuously, and when the child is sent to the institution's camp for a period of three to four weeks during the summer, the same record cards are continued.

All cases in which errors or discrepancies of recording were suspected were excluded from the following analyses. Since in certain cases the second and third menstruation may follow the previous period by a considerable lapse of time, no case is recorded who had not resided in the home and under observation for six months prior to the first recorded menstruation.

The medical records were examined, and led to the exclusion of those cases with a history of endocrine dysfunction, thyroid trouble, obesity, pneumonia, etc. There are no cases of suspected tuberculosis in the institution. As a result of such rejections, the cases in this study may be considered medically normal.

Almost all the children were born in the United States; the majority in New York City, and of Jewish parents. A few instances may have

a single Jewish parent, but this does not appear on our records. The material, therefore, is selected from a homogeneous group.

By the application of the above standards of selection the number of cases suitable for study was reduced to 250 medically normal girls with known and verified date of birth and of menarche, who resided in the home for at least six months prior to their first menstruation. Included in this series are 100 cases who have had twenty or more menstrual periods. (A minimum of twenty periods was chosen arbitrarily.) This group of 100 individuals had a total of 3,140 menstrual cycles, and was studied to analyze early menstrual experience.

The time covered represents menarches occurring over a period of six years, from 1926 to 1932, with the majority in the last three years.

The term *menarche* (Gr. *mene,* month *-arche,* beginning) is defined as "the beginning of menstrual function." As used in this study it means merely the first menstruation; the advent of the menses without implication of the establishment of a rhythmic uniformity of function. The expression usually employed, *puberty,* (L. *pubertas* from *puber,* adult), defined (Webster) as "the earliest age at which a person is capable of begetting children" is unsuitable. Laboratory and anthropologic observations provide evidence that the physiologic possibility of conception and subsequent delivery is extremely remote at the time of the first menstruation. The synonymous use of puberty and menarche therefore, is incorrect. Neither term should be confused with sexual maturity (Engle, 1931). The term puberty should be assigned to the undefined period during which the pituitary-gonad complex is being stabilized.

It will be in keeping with current concepts of a developing organism if we consider puberty as the physiologic phase during which time sex functions and characteristics develop, under the proper hormonic stimuli, and during which period, in girls, the menarche occurs. The appearance of the secondary sex characters has been shown to take place in about equal proportions before and after menarche (Preisel and Wagner, 1930). Puberty is a developmental state during which many physiologic processes, somatic and sexual, occur, and menarche is but a single incident in the process. The two terms cannot be used interchangeably. The relation of menarche to puberty is well stated by Preisel and Wagner: "Die *Menarche* muss nicht den Schlusstein der Pubertätsentwicklung darstellen, ist aber unter physiologischen Verhältnissen niemals ein Frühsymptom."

MENARCHES OF 250 JEWISH GIRLS

There are relatively few series of studies mentioning first menstruation in girls in which both the dates of birth and menarche are accurately known. For this reason many of the recorded data, particularly for the Naturvölker, are little more than an impression.

Bolk (1923) reports a series of cases in which the year and month of the first menstruation are known, and a second group in which the year of life is recorded. Dickinson and Beam (1931), Bolk, and Gould and Gould (1932) testify to the inability of adults to recall the year, much less the month or day of the menarche.

It is common experience that the testimony of clinical patients is notoriously unreliable and is too often influenced by the suggestion of one who hurriedly records the history.

In this series, the year, month and day of both the birth and menarche are known, and the age can be calculated in years and fractions of a year to the day. The table of Pearl and Miner (1932) was invaluable for this purpose.

The essential data are recorded in Figure 1. The average age of menarche is 13.533 years, the range being from 11.044 to 16.310 years.

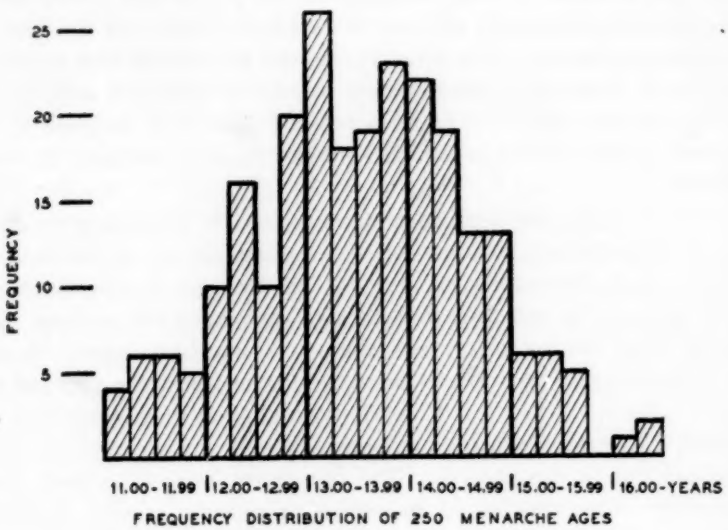

FIG. 1. FREQUENCY DISTRIBUTION OF 250 MENARCHE AGES BY QUARTER YEARS

Average age, 13.533 years. Extreme range, 11.044 years to 16.310 years.

It is noted that the spread is fairly uniform, with skewnes to the left. The earlier literature on age of menarche was assembled by Novak (1931), and will not be discussed in this place.

There is no measure of comparison between these girls in this institution and others residing at home in reference to the age of menarche. Boas (1932) has compared certain of the girls represented in this study with two non-institutional groups. He reported that 185 of these institutional girls averaged 0.4 of a year older at menarche than the non-institutional Hebrew and non-Hebrew children composing his study. A valid comparison within this group was made possible by the correlation of years of residence in the institution with age of menarche. The age at admission was determined, again using the table of Pearl and Miner, recording years and fractions to the third place. This age at admission was deducted from the age at menarche, giving the years of institutional residence prior to the first menstruation. The average length of pre-menarche residence in this institution was 4.0 ± 2.2 years with a range from 6 months to 8.5 years. The coefficient of correlation between the menarche-age and the length of pre-menarche residence was found to be 0.11.[2] With so small a number of cases this correlation is negligible. There is no evidence of a relation between the age at menarche and the number of years of institutional residence. It is, therefore, probable that these cases represent a cross section of conditions occurring in the same ethnic and social class in New York City.

SEASONAL OCCURRENCE OF MENARCHE

An analysis was made of the monthly and seasonal distribution of incidence of these 250 menarches. The graph in Figure 2 shows the actual number of menarches which occur each month of the year and the same data distributed by seasons. For the seasons, the winter months include December, January and February; spring, March, April and May; summer, June, July and August; and autumn, September, October and November. In both charts a distinct drop in the incidence of menarche occurring in the summer is noticed; only 18.0 per cent

[2] The formula used in the calculation of coefficient of correlation was:

$$r = \frac{\frac{\Sigma xy}{n} - M_x M_y}{\sqrt{\frac{\Sigma x^2}{n} - M_x^2}\ \sqrt{\frac{\Sigma y^2}{n} - M_y^2}}$$

of the menarches in these 250 cases occurred in the summer months of June, July and August; 25.2 per cent in the autumn months; 29.6 per cent in the winter and 27.2 per cent in March, April and May.

To test the veracity of the low summer incidence halved random samplings of these data were plotted. The first 125 cases were distrib-

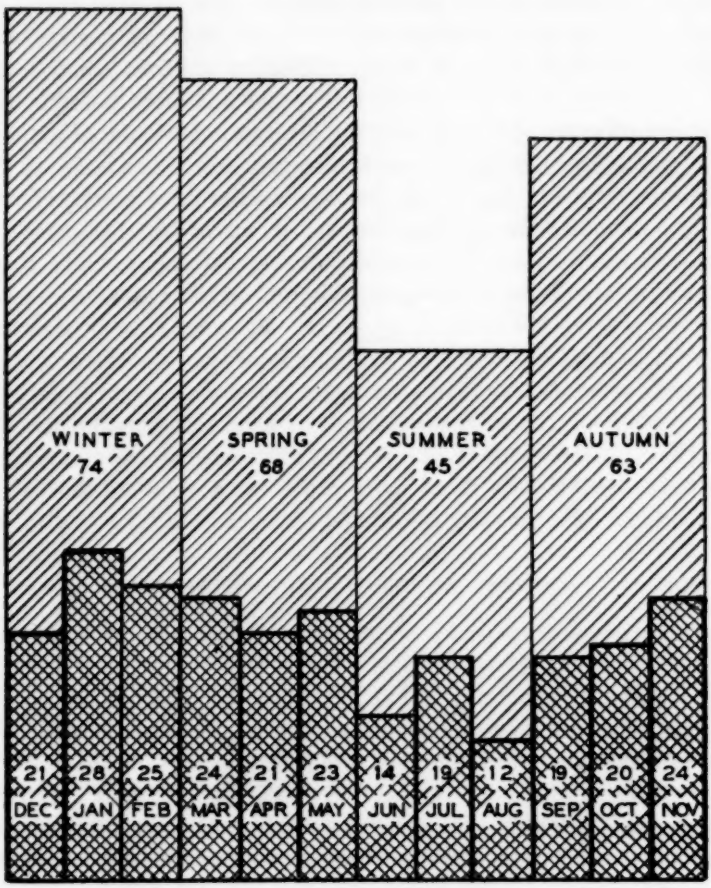

FIG. 2. FREQUENCY DISTRIBUTION OF OCCURRENCE OF MENARCHES BY MONTHS AND BY SEASONS
The figures are numbers of cases.

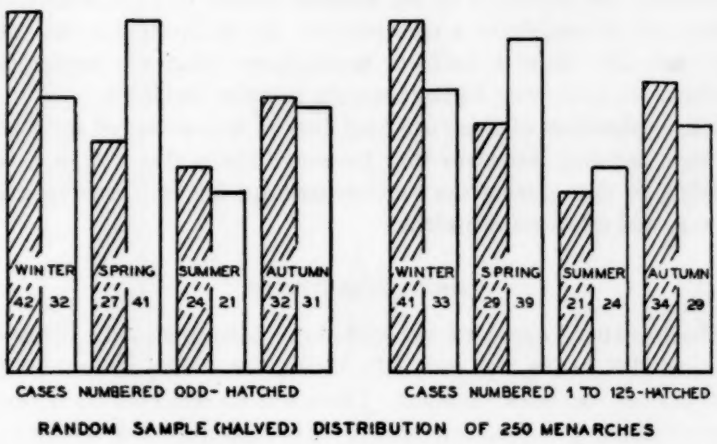

FIG. 3. VERIFICATION OF THE DATA PRESENTED IN FIG. 2 BY METHODS OF RANDOM SAMPLING

Graph on left representing the odd numbered cases (hatched) and the even numbered cases (unhatched). Graph on right representing the first 125 cases (case numbers 1-125) hatched, and the second 125 cases (case numbers 126-250) unhatched. The low summer incidence is shown to be not a chance distribution.

uted and similarly the second 125 cases (Fig. 3). In a second random sampling the odd numbered cases and the even numbered cases were plotted. It should be stated that the serial numbers were given to a case by chance as the cases were collected from alphabetically arranged files, and unsuitable cases eliminated on a basis of criteria discussed above. As a third method of verification, the menarches of children born during the winter months (Dec., Jan., Feb.) were distributed against the menarche dates of those born during the summer season (June, July, Aug.).

The summer season is consistently low in all methods of sampling. Differences between the two groups were noted in the spread between the winter and spring seasons. These methods show that the high incidence of winter menarches indicated in Figure 2 is not a valid picture as this peak may be in either the winter or spring, depending on chance. Thus while the menarche incidence in winter and spring is considered to depend on a chance grouping either interchangeable or overlapping, not confirmed by three methods of random sampling, the

consistently low incidence of the summer occurs in each redistribution of data and is considered a true picture. In all groupings the autumn menarches also show a uniform trend, lower than the winter-spring divisions, but uniformly higher than the summer incidence.

The explanation of these seasonal factors is commented upon below. We have satisfied ourselves that the condition is due not to a faulty recording of data during the summer months, but is a true expression of a seasonal effect on menarche.

MENSTRUAL CYCLES

The menstrual cycles of 100 girls have been analysed. These data were included in the 250 menarche series, for which at least 20 menstrual periods had been recorded. There was no other selection than the rigorous exclusion discussed above. The material was handled with especial care in regard to the recording of menstrual cycles during the summer. The child was away from the institution for a limited time, not exceeding four weeks, in the school camp, during the summer, but the entire case histories have been examined to assure the accuracy of recording. These cases are felt to represent the true condition with a minimum of artefact.

MENSTRUAL CYCLES OF THE GROUP

The menstrual interval was determined by counting from the first day of one menstruation to the day preceding but not including the first day of the next bleeding. There are 3,140 menstrual cycles. The shortest period of time is represented in the series by Case 47, who experienced 20 menstrual periods in 18 months. The greatest length of elapsed time in this series is that of Case 133 who experienced 69 cycles over an elapsed period of 5 years and 4 months (Fig. 9). The frequency distribution of the 3,140 menstrual cycles is shown in Figure 4. The range is from 7 days to 256 days with a mode at 28 days, and a mean of 33.9 days. The number of days most frequently occurring falls between 17 and 45 inclusive, with 2,728 cycles (86.99 per cent). 2.45 per cent of all cycles (77) are less than 17 days and 13.01 per cent (335) are 46 or more days. The average standard deviation from the mean is $\pm$ 14.28 days with an extreme range of standard deviations in individual cases from $\pm$ 3.9 days to $\pm$ 39.0 days.

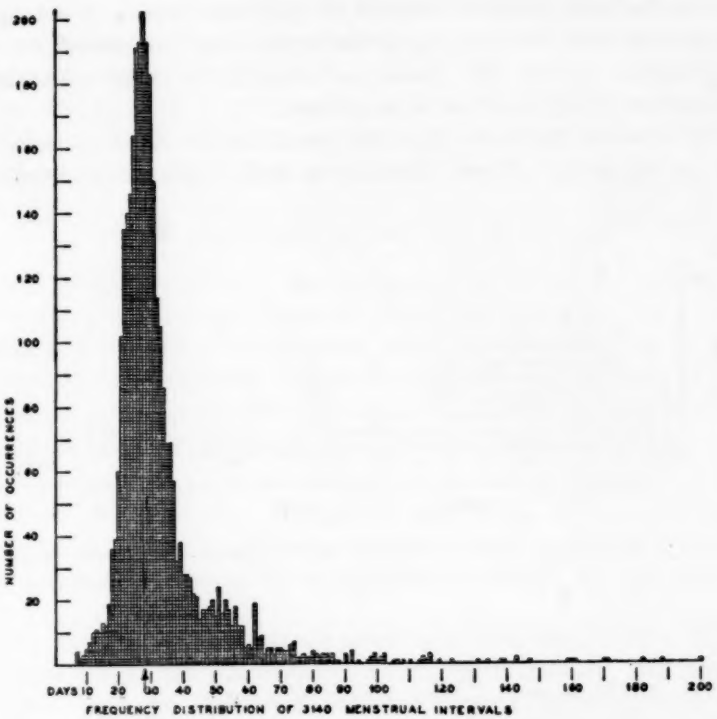
NUMBER OF OCCURRENCES
DAYS 10 20 30 40 50 60 70 80 90 100 120 140 160 180 200
FREQUENCY DISTRIBUTION OF 3140 MENSTRUAL INTERVALS

FIG. 4. FREQUENCY DISTRIBUTION OF 3,140 MENSTRUAL CYCLES OF 100 GIRLS

Two places, one at 238 days, the other at 256 days are omitted from the graph. Mean length of cycles, 33.9 ± 14.28 days; modal length, 28 days; extreme range, 7 to 256 days.

It is of interest, in view of the traditional concept of a 28 day cycle, that in these 3,140 instances 28 days *is* the most commonly recurring figure, but a 28 day interval is modal in only eight of the individual cases. That is, in only 8 per cent of the girls studied is the mode of the days of the menstrual cycle at 28 days. The modes in these 100 individual cases may be represented by a low interval of 20 days in one case to one in which the individual mode is 44 days. Two cases had no modal figure; no two menstrual cycles were of the same number of days (see Fig. 10). Thirteen of the cases had 29 day modes; 10 cases, 25 days, and 11, 27 days.

Thus the most frequent number of days constituting a menstrual cycle was 28 days when all menstrual cycles were considered but the most frequent number (i.e., modal) of days in the menstrual cycle of individual cases may be from 20 to 44 days.

The standard deviations from the mean for the hundred cases are given in Figure 5.[3] These figures are much higher than would be

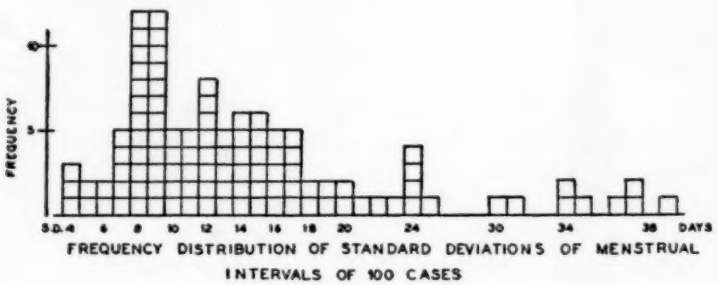
FREQUENCY
S.D. 4 6 8 10 12 14 16 18 20 24 30 34 38 DAYS
FREQUENCY DISTRIBUTION OF STANDARD DEVIATIONS OF MENSTRUAL INTERVALS OF 100 CASES

FIG. 5. FREQUENCY DISTRIBUTION OF THE STANDARD DEVIATIONS FROM THE MEAN OF MENSTRUAL INTERVALS OF 100 INDIVIDUAL HISTORIES

expected a priori, but there is no norm for comparison. Novak (1933) has said that "marked irregularities are common during the first few years after puberty" (menarche), but heretofore an exact measure has not been made. The data here presented may not be representative of conditions in a larger sample of the population or in an equal number of non-institutional girls. The conclusions are presented as being true for this group of children under the stated conditions. The menstrual histories of a few representative cases are presented in detail by means of graphic analysis. These graphs present the data of typically regular cases (Figs. 11, 12) and typically irregular cases (Figs. 13, 14).

The irregularity of the cycle in medically normal adult women has been presented recently by King (1933) and by Edward Allen (1933). The latter writer gives the number of days in the cycle for six women.

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[3] The use of the formula $\sigma = \sqrt{\frac{\Sigma f \Delta^2}{n}}$ or the so-called "short method," $\sigma = \sqrt{\frac{\Sigma f \Delta^2}{n} - c}$ (where c is the correction factor) entails the computation of deviations (Δ). In these studies a more convenient formula $\sigma = \sqrt{\frac{\Sigma x^2}{n} - M_x^2}$ where x is the actual measure and $M = \frac{\Sigma x}{n}$, the mean, was employed.

From Allen's data (Table II, p. 707) we have calculated that in Case A with 25 cycles the range is from 16 to 55 days; the mean 26.4 with a standard deviation of ± 7.44 days. Case F, 28 cycles, is similar, with a range of 21 to 41 days; mean 30.7 ± 4.9. Allen's data do not permit an extended examination but it is evident that for adults the irregularity is of the same nature as that presented here for the adolescent cases.[4]

TREND OF VARIABILITY WITH TIME AND AGE

The variability of menstrual cycles decreases as the menstrual life increases, as is shown in Figure 6. The range and the average of the standard deviations of those cases which have experienced 20 to 24 menstrual cycles is greater than those which have experienced 25 to 29 cycles, and falls steadily with increasing elapsed time since the menarche. The range of variability is markedly lessened with increased menstrual experience.

Although the number of cases in each group is small, it may be concluded that a distinct trend toward menstrual regularity occurs subsequent to the experience of from 20 to 24 menstrual cycles. After the twenty-fourth cycle a definite progressive trend toward regularity is seen.

The irregularity of the menstrual cycle is not correlated with age at menarche (Fig. 7). The number of cases in each menarche age group is small, but it is clear that in these cases the menstrual experience, or elapsed number of cycles, is of greater importance in establishing a trend toward normality than is the age of the individual at menarche.

MENSTRUAL INTERVALS OF EXCESSIVE LENGTH

An examination of the frequency distribution of all menstrual cycles (Fig. 2) reveals that some intervals are of excessive length. The

[4] Since this manuscript was sent to press, an extended and careful study by Fluhmann (*Amer. Jour. Obst. & Gyn.*, vol. 26, p. 642, 1933) on the length of the menstrual cycle in adult women has appeared. The analysis of 747 cycles shows a mean length of 30.4 days, with an extreme range of 11 to 144 days (97 per cent between 18 and 42 days). Comparison of Fluhmann's data on adults and the present data on adolescents reveals a closer agreement between length of menstrual cycles than has been previously suspected.

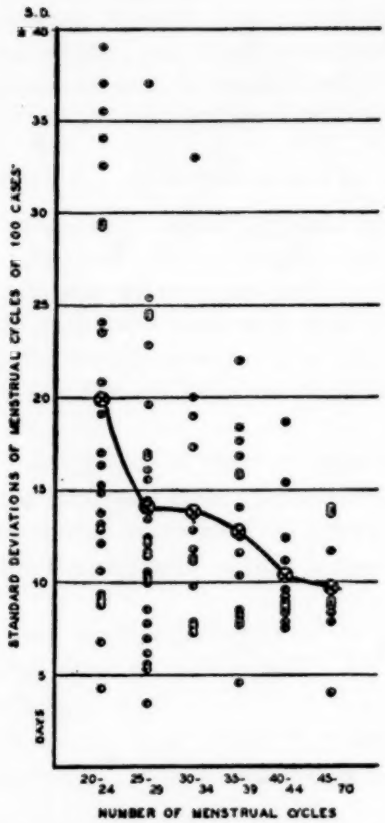

FIG. 6. TREND TOWARD MENSTRUAL REGULARITY AS A FUNCTION OF MENSTRUAL EXPERIENCE

The standard deviations from the mean of each case in the group are shown on the ordinate. The numbers of menstrual cycles experienced are represented on the abscissa in groups of five cycles. The curve connects the average standard deviation of each menstrual experience group. The graph shows clearly the decrease in extreme range of each group with increasing menstrual age, and a tendency of the average toward a less variable rhythm.

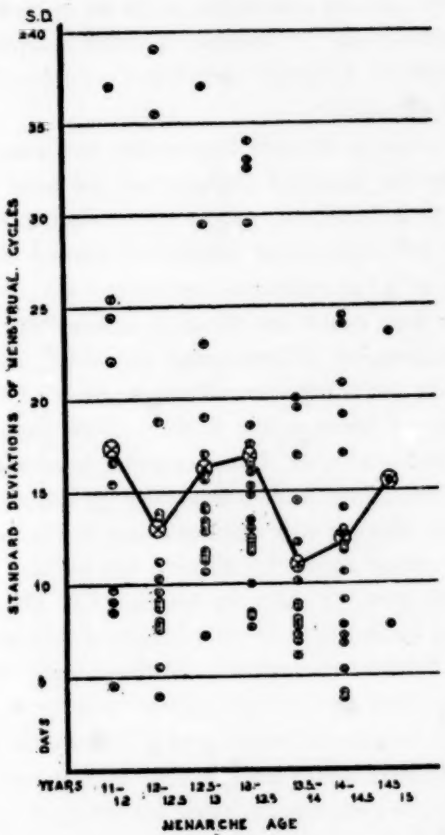

FIG. 7. GRAPH SHOWING THAT THE VARIABILITY OF THE MENSTRUAL CYCLE IS NOT A FUNCTION OF MENARCHE AGE

The same standard deviations which are presented in Fig. 6 are reassorted on the abscissa and plotted against the age of the individual at menarche. The age is presented by half years.

most frequently occurring length of the menstrual cycle is 28 days. Any cycle which has extended beyond the second expected period, that is, more than 56 days, can be considered to be an excessively long cycle, a temporary amenorrhea. However, a more adaptable method of adjusting the length of a "long" period is to employ the mean length and the standard deviation.

The adopted measure of such long cycles was accepted as a figure representing twice the standard deviation of the total cycles added to the mean $(33.9 + 2\ (11.8) = 57.5)$. A deviation as large as this would occur only 228 times out of 10,000 in a normal distribution.

Of this series of 3,140 menstrual cycles, 202 are more than 57 days in length. These long cycles are those in which there is a temporary suspension or suppression of menstrual functions. Seventy-eight of the 100 girls in this series experienced one or more of these long intervals. Twenty-six of these cases, slightly more than one-fourth of all the cases, experienced long first menstrual intervals, i.e., the cycle initiated by the first menstruation was over 57 days. In four cases, this first long cycle was the only one occurring in the menstrual history which was more than 57 days. Of all girls one in four will have a first menstrual interval over 57 days in length. Of all girls who have experienced a long cycle, one in three will have a first interval in excess of 57 days. A further examination of these long intervals reveals the interesting fact that they do not appear to occur at random in the menstrual histories, but are expressions of a seasonal influence (Fig. 8).

Those long intervals which are initiated by a menstruation in July are more than twice as numerous as those occurring in any other month. An interval in excess of 57 days may extend beyond two months, which is reflected in the fewer number of long cycles which are initiated by a menstruation in August and September.

The seasonal distribution (Fig. 8) of the periods which begin these long cycles shows that almost twice as many start in summer as in any other season. The causes of missed periods and temporary amenorrhea are many, but it is evident that factors correlated with the summer months have an important and hitherto unrecognized influence.

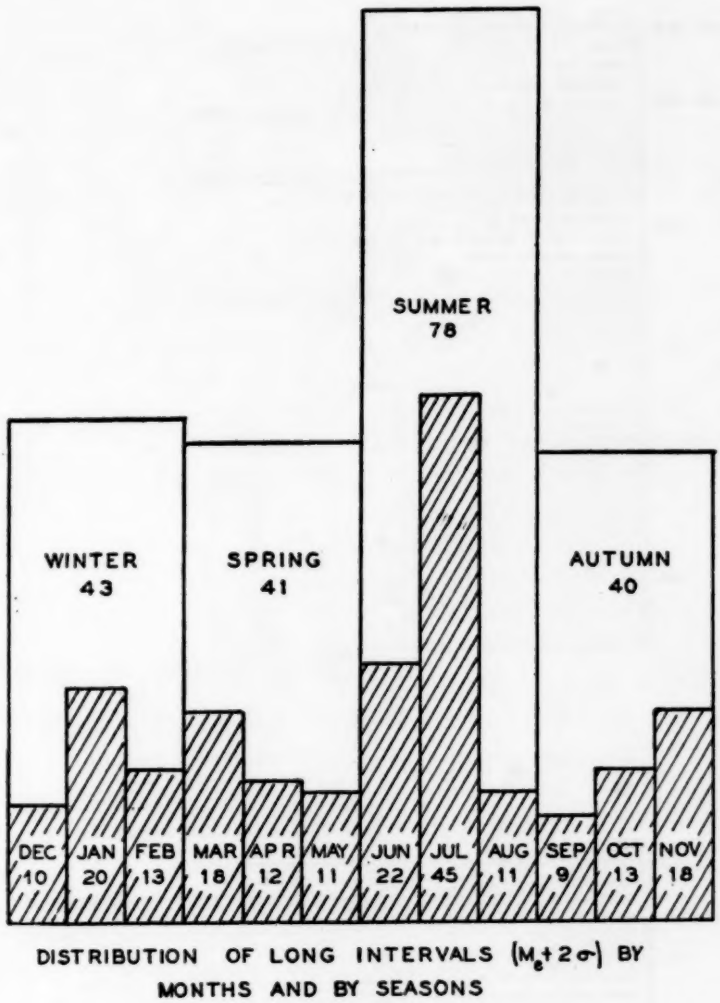

FIG. 8. GRAPH SHOWING FREQUENCY OF TEMPORARY AMENORRHEA BY MONTH AND SEASON

The number of instances in each month or season is given. See text for method of determining a long cycle.

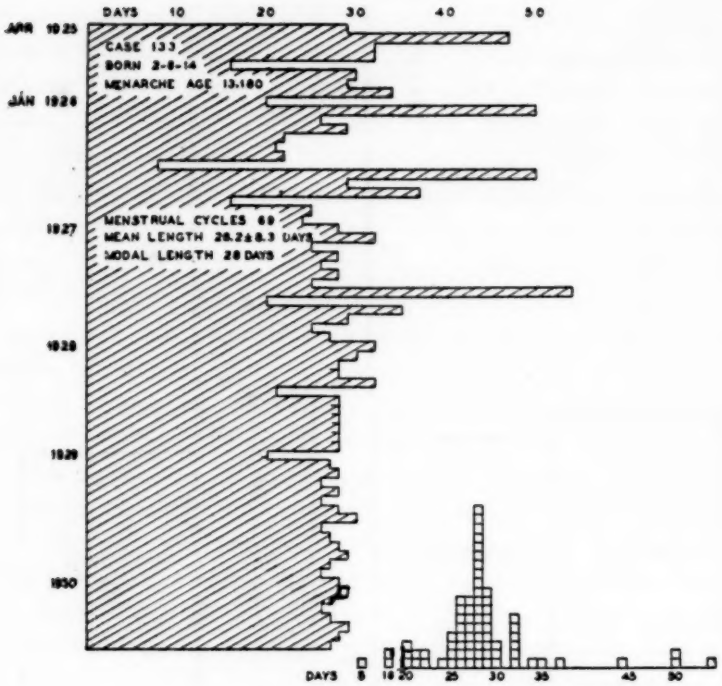
DAYS 10 20 30 40 50
APR 1925
CASE 133
BORN 2-8-14
MENARCHE AGE 13.180
JAN 1926
1927
MENSTRUAL CYCLES 69
MEAN LENGTH 28.2±8.3 DAYS
MODAL LENGTH 28 DAYS
1928
1929
1930
DAYS 5 10 20 25 30 35 45 50

FIG. 9

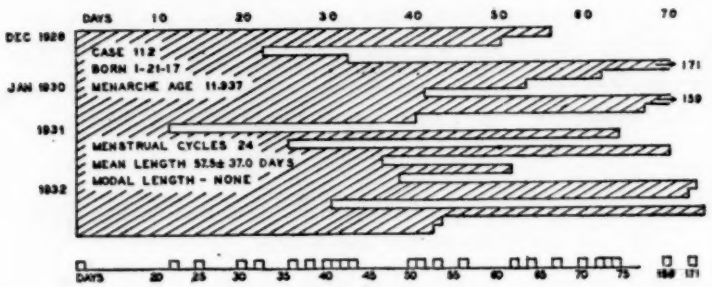
DAYS 10 20 30 40 50 60 70
DEC 1928
CASE 112
BORN 1-21-17
MENARCHE AGE 11.937
171
159
JAN 1930
1931
MENSTRUAL CYCLES 24
MEAN LENGTH 57.5± 37.0 DAYS
MODAL LENGTH - NONE
1932
DAYS 20 25 30 35 40 45 50 55 60 65 70 75 159 171

FIG. 10

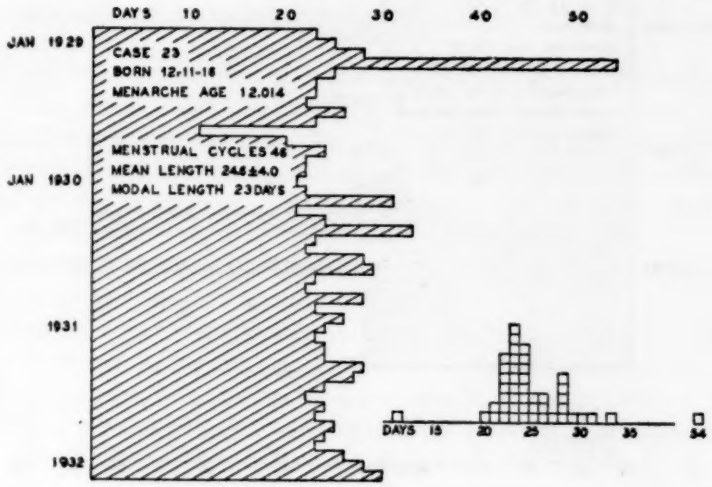
DAYS 10 20 30 40 50
JAN 1929
CASE 23
BORN 12-11-18
MENARCHE AGE 12.014
MENSTRUAL CYCLES 46
MEAN LENGTH 24.6±4.0
MODAL LENGTH 23 DAYS
JAN 1930
1931
1932
DAYS 15 20 25 30 35 54

FIG. 11

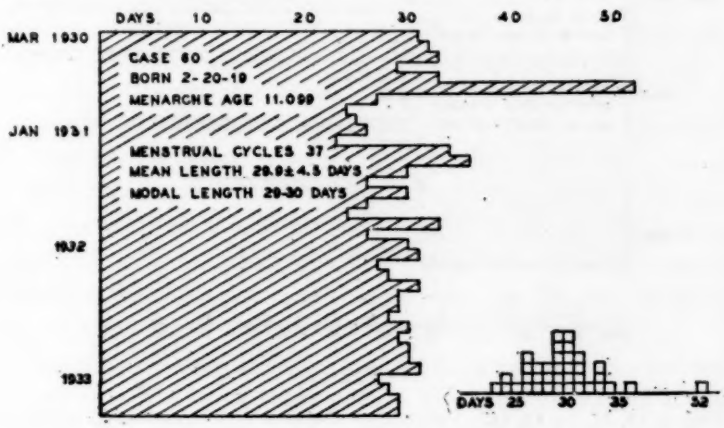
DAYS 10 20 30 40 50
MAR 1930
CASE 60
BORN 2-20-19
MENARCHE AGE 11.099
JAN 1931
MENSTRUAL CYCLES 37
MEAN LENGTH 29.9±4.5 DAYS
MODAL LENGTH 29-30 DAYS
1932
1933
DAYS 25 30 35 52

FIG. 12

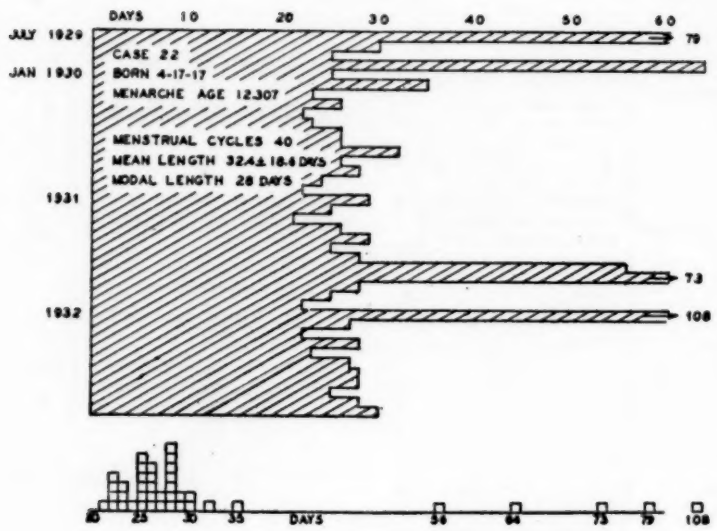

FIG. 13

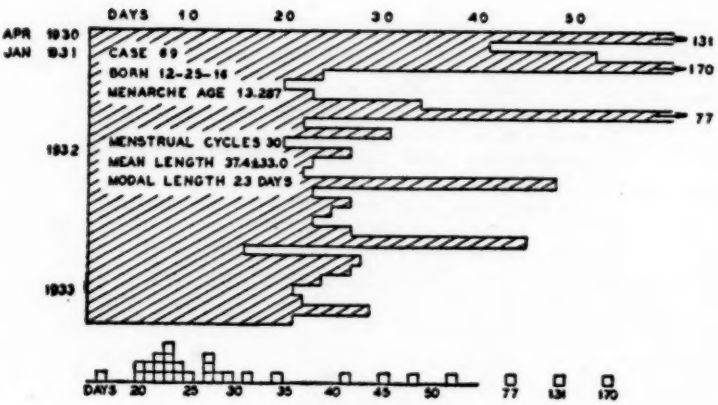

FIG. 14

FIGS. 9, 10, 11, 12, 13, 14. PROJECTION GRAPHS OF INDIVIDUAL MENSTRUAL HISTORIES SHOWING LENGTH OF EACH MENSTRUAL CYCLE AS THEY OCCUR CHRONOLOGICALLY

The frequency distribution of cycles in days is also shown.

DISCUSSION

1. Seasonal Trend

It has been shown that, for the data studied, a low percentage of menarches and a high percentage of temporary amenorrheas occur during the summer months. The concept of a relationship between physiological and epidemiological occurrences and seasonal or meteorological factors is not new. Mills and Senior (1930) have suggested that variations in conception rates in different localities may be correlated with climatic factors. Reed (1925) also has pointed out seasonal trends in birth rates in Boston and England.

Hartman (1933) has demonstrated that in macacus monkeys, ovulation is inhibited during the summer months in his Baltimore colony. A single conception, which may be the exception which proves his rule, occurred in his colony in the summer quarter (June, July, August); the peak of ovulation incidence comes in the months of November, December and January. He also records greater irregularity of the menstrual cycle, an increase in amenorrhea and lessened degree of response in the color of the sex skin during the summer. In our own monkey colony the only failures in inducing ovarian activation with extract of the anterior pituitary gland have occurred during the summer months. Further analysis is being made of this point.

There is no implication that such seasonal relationships as occur in monkeys should be so clearly expressed in adult women. For the pubertal girl, however, it was demonstrated above that for our data there is a marked difference in menarche incidence between the summer months and the remaining quarters of the year. A factor of similar physiological nature is seen in the increase in the number of cases of temporary amenorrhea during the same period. The pubertal individual is a physiologically unstable organism, in which slight extra-somatic factors may profoundly influence somatic responses, so that phenomena may appear here which disappear with maturity.

In analysing the data in Figures 2 and 8, in reference to incidences of menarche and periods of amenorrhea it should be pointed out that the phenomenon of menstruation is an end result of a longer physiological process. The real causative factors must be recognized to occur a month or more previous. Thus if a girl menstruates in January, ovarian activity which has stimulated growth of the uterine mucosa has

occurred some weeks previous to the bleeding. The menses are a result, probably, of the withdrawal of the stimulating action of the hormone of the ovarian follicle (oestrin), or of the withdrawal of the stabilizing hormone of the corpus luteum (progestin). When discussing pubertal menstruation in these cases no statement can be made regarding the type of bleeding which has occurred. There is a strong probability that the bleeding during early puberty is not always from an endometrium prepared by a corpus luteum of ovulation. Whether it is a bleeding from a progravid endometrium, it is, in non-pathological bleeding, an end result of ovarian activity which occurred earlier.

The pioneer work of Rowan (1931) and Bissonnette (1931) in demonstrating the influence of light on the genital organs of migratory birds, and Bissonnette's (1932) further demonstration of the influence of various components of light on the breeding behavior and capacity of ferrets are not as yet directly applicable to the problem under discussion. Nevertheless, they clearly indicate the necessity of a search for extra-somatic, recurring factors which may be responsible for the observations made from an analysis of our data.

A further suggestion of Whetham (1933) may be offered. She has demonstrated that in all latitudes the seasonal egg production of domestic fowls is in general correlated with total hours of daylight. In this connection Whetham has suggested that the influencing factors "may be caused by change in the light ration rather than by the quantitative amount of light."

These foregoing suggestions are put forth to indicate the need for a more complete recording of data relating to human menstrual histories including subtle seasonal factors which may prove to be of biological interest.

2. The Irregularity of the Menstrual Cycle

Data accurately collected from adult women indicate that the recurring menstrual cycle is not rhythmic in a true calendar sense, but is a recurring phenomenon which is rhythmic within a standard deviation of three to seven days. With this extreme range of variability in the length of the menstrual cycle in normal mature women it is evident that the sub-adult cases here reported tend toward a "normality of variability" with increasing menstrual experience which is, in general, comparable to that of adults. With a recognition of the degree of irregularity occurring in the adult woman it may be accepted that these cases

represent a cross section of conditions obtaining in pubertal girls and are not greatly affected by factors connected with institutional living.

The traditional lunar relationship of the menstrual cycle has come down to us, not only in the term menses (L. *mensis*, month) but also in the concept of a cycle regularly recurring every 28 days. Such a cycle may occur, as in our data, as a modal frequency, rarely as an average length of cycle, in a large number of individuals if the dates of menstruation are accurately recorded.

Menstrual records of a score of mature married and single women, extending from one to six years, which we have meticulously recorded, add some evidence to that reported by King and by Allen, being entirely uniform with their findings.

It is possible that medical case histories will eventually cease to report that the "patient first menstruated at the age of thirteen, menstruation recurring regularly every 28 days." A more accurate statement would state in effect that the menarche occurred with the normal age range, and that the menstrual cycle recurred within the limits of normal variability.

SUMMARY

1. This report deals with the age at menarche of 250 girls and with 3,140 menstrual cycles of 100 of the same group of girls.

2. The date of birth and date of menarche are known for each case. Only cases with uncomplicated medical histories are included. The average age at menarche is 13.533 years with extreme range of 11.044 years to 16.310 years.

3. There is no correlation between the age at menarche and the length of residence within the institution.

4. A distinct seasonal incidence in the occurrence of menarches is demonstrated. Only 18 per cent of the total occur during the summer months of June, July and August.

5. One hundred of the girls studied had experienced from 20 to 69 menstrual cycles, a total of 3,140, with an extreme range in days from 7 to 256, mode at 28 and a mean of 33.9. The average standard deviation from the mean for each individual of the 100 cases is ± 14.28 days. The standard deviation from the mean of the 3,140 cycles is ± 11.8 days.

6. The variability of the earliest menstrual cycles is high, and decreases with menstrual age. There is no direct relationship between the variability of the cycle and the age at menarche.

7. A study was made of the occurrence of temporary amenorrheas. All cycles over 57 days in length were studied. A menstrual interval greater than 57 days was the one following the initial period in 26 per cent of the cases.

8. The long intervals initiated by a period in July are twice as numerous as those initiated in any other two months of the year. Periods of amenorrhea are especially frequent during the summer months, although they occur throughout the year. This is probably an expression of the same factors which account for a low incidence of menarches during the summer months.

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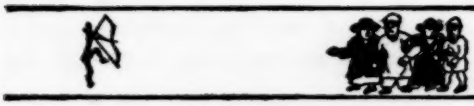


PRELIMINARY REPORT ON THE MEASUREMENT OF OSSIFICATION OF THE HAND AND WRIST[1]

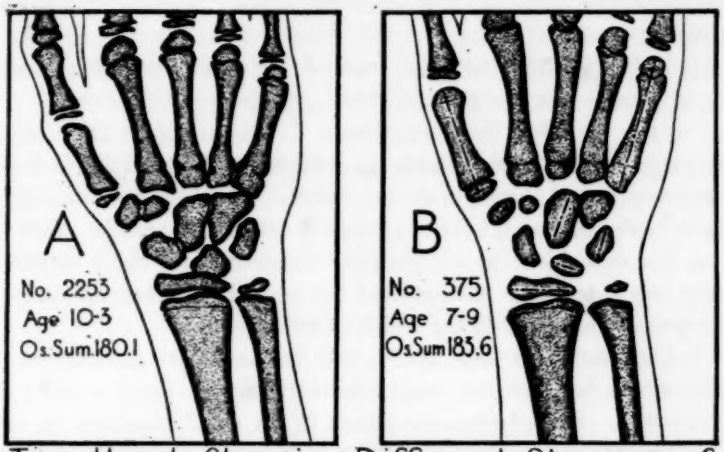
BY PSYCHE CATTELL

DR. PRESCOTT in his monograph entitled *The Determination of Anatomic Age in School Children and Its Relation to Mental Development*[2] was the first to propose a measure of ossification which could be made objectively. Using X-ray plates from the Growth Study conducted since 1922 by Walter F. Dearborn, he tried out a number of methods of measurement which included measurements of the area of each of the carpal bones with a planimeter, measurements of the space between the bones to determine the amount of space which must still be filled before the bony development is complete, the measurement of the largest diameter of the bones, the shortest distance between the bones, and measurements of the size of the wrist as distinct from each bone separately.

After considering the advantages and disadvantages of the various methods, he selected the sum of the widest diameter of eight carpal bones divided by the width of the wrist as the most practical method. The purpose of dividing the sum by the width of the wrist was to take into account the size of the individual child apart from maturity. The hand of a large immature child may show a larger area of bony tissue than that of a smaller but more mature child. For example, the hand shown on left of Figure 1 obviously represents a more mature hand than the one on the right, even though there is little difference in the actual amount of bony tissue, and judgment of the relative maturity of the

[1] The material for this investigation was obtained from the Growth Study directed by Walter F. Dearborn of the Graduate School of Education of Harvard University (See *School and Society*, Vol. 18, pp. 131-135 and Vol. 20, pp. 515-518), with the exception of the data on infants which were obtained from the Infant Growth Study directed by Harold C. Stuart of the School of Public Health of Harvard University.

[2] Harvard University Press, 1933.



Two Hands Showing Different Stages of Development with equal Ossification Sums.

Figure 1

two hands, if based on the sum of the measurements alone, would obviously be at fault.

Dr. Prescott found that when two experienced workers ranked independently a group of X-ray plates of children of the same age and sex in order from the least to the most mature, a correlation coefficient of .98 existed between the two rankings, and that his objective measure of ossification, just described, correlated with the subjective judgments to the extent of .95 to over .98. All this looked promising. He published medians for six-months and one-year age groups. His norms show a regular increase from year to year up to the age of twelve for girls and fourteen for boys. From these data Dr. Prescott concluded that insofar as the development of the wrist was concerned, maturity was reached at twelve in girls and about two years later in boys.

When this study came out, it was the best on the subject, and perhaps still is, especially for the younger children. But we believe that it can be improved upon with the aid of the additional material now at hand. Dr. Prescott did all his analytical work on first and second grade children and then assumed that the same measures would be equally valid for older children. As no repeated measurements were available at that time, he did not discover that the bones were still increasing in size from

year to year even after the age when the median anatomic index ceased to increase.

It is quite possible for every one of Dr. Prescott's nine measurements to increase in size and for the index to actually decrease. This is due to the fact that the denominator of the fraction, i.e., the wrist width, may increase in size faster than the numerator, which is the sum of the diameters of the eight carpal bones. The result, of course, is a decrease in the index, although growth is still taking place. This difficulty is not so evident in the younger children since their carpals are growing at a rate which assures that the annual increment of their sum will be greater than that of the width of the wrist.

It is important that bone size should be taken into account in order to differentiate between the small relatively mature hand and the large immature one. But all evidence points to the conclusion that an index, such as Dr. Prescott's, in which both numerator and denominator increase with age, cannot give satisfactory results. The bones are, apparently, very irregular in growth, first one bone then another growing more rapidly. This played havoc with each of the indices that were tried out. Both numerator and denominator may continue to increase in size, but the proportional increase varies, causing the indices to rise and fall.

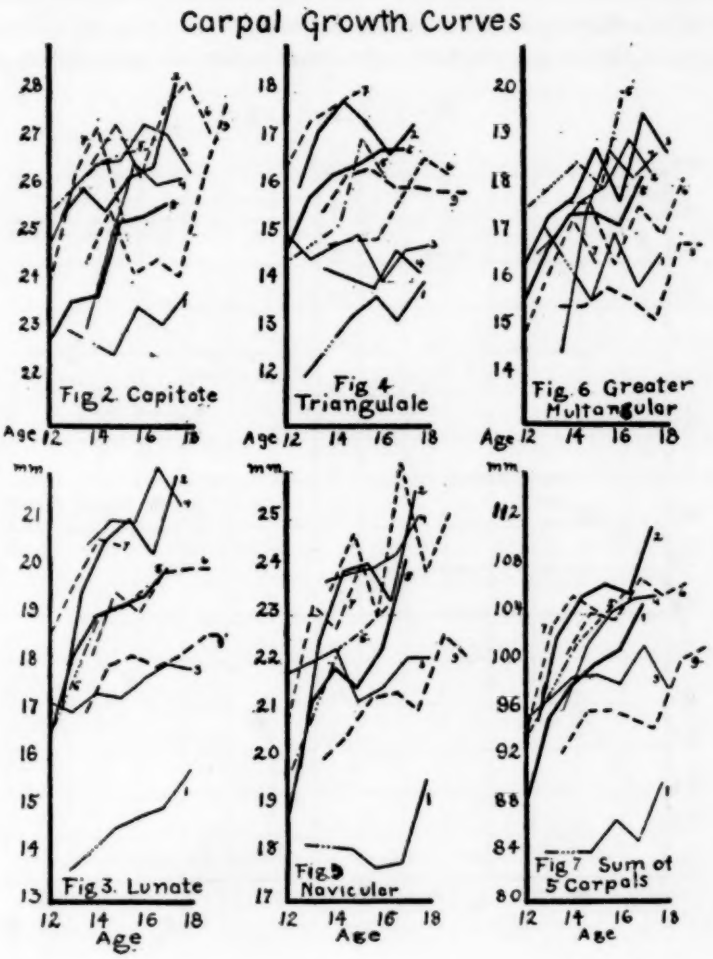
The first step in another attempt to get at the measurement of ossification was to select from the files the X-ray plates of nine feeble-minded girls who had had several X-ray plates taken between the ages of twelve and eighteen.[3] Every measurement for which bony landmarks could be found was made on each of the fifty-four X-ray plates, thirty-nine on each, making a total of over 2,000 measurements. Records of the feeble-minded instead of school children were used because at the time this part of the study was made, the school children for whom we had records of repeated examinations were still under the age of fifteen.

It soon became evident that in the majority of cases all the wrist bones increase in size up to the ages of fourteen or sixteen or beyond, but that the increment of growth is small—very small. At the ages of fourteen and fifteen the increment in the majority of cases is below .5 millimeters. This was one reason for the difficulty found in determining measures which showed growth. When the measures were first tried

[3] Girls were used throughout this study as many had attained their full growth while most of the boys were still growing.

out on small groups of twenty cases or so, containing different individuals at each age, a few especially large or small hands were sufficient to cover up the fact that there was a continuous, though small, increase in the size of the bones during at least the greater part of the period of general growth.

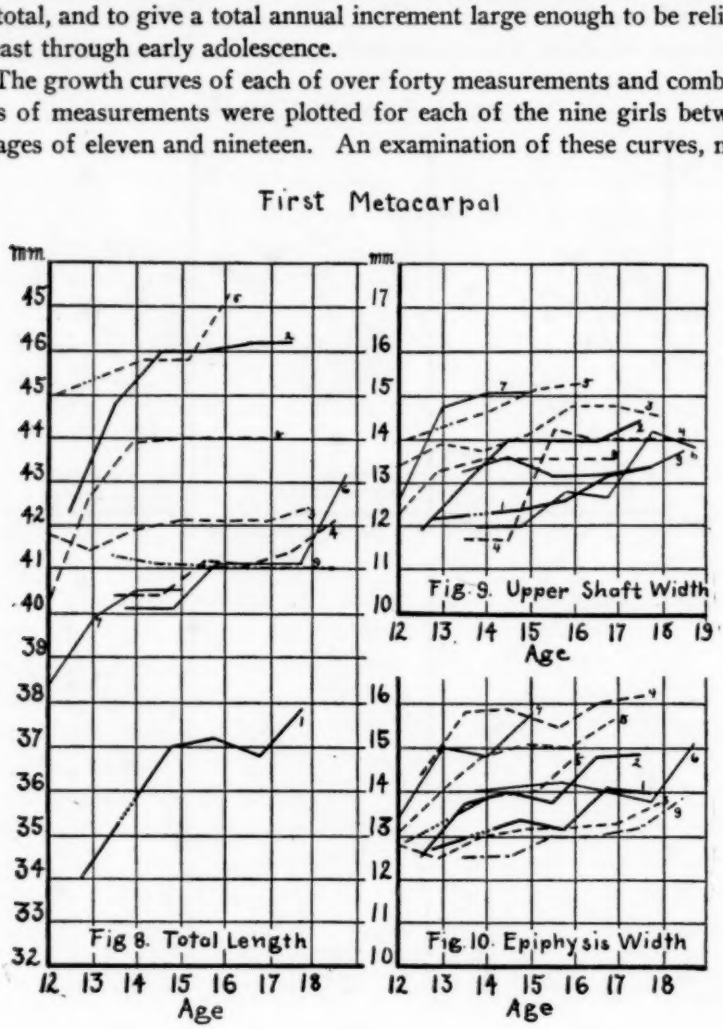
The small increments appear reasonable when it is remembered that the annual increment in total stature at the ages of thirteen and fourteen is, on the average, under 3 centimeters. The average height at thirteen is about 155 centimeters, while the average size of the



carpal bones is about 2 centimeters. Therefore, should the increments of growth of the bones of the wrist be proportional to that of the total stature they would average under 0.4 millimeters. A second difficulty has been that even with the most careful measuring an accuracy greater than .2 or .3 millimeters cannot be expected. It, therefore, appeared that the number of measurements taken should be large enough to cause the small random experimental errors to compensate for one another in the total, and to give a total annual increment large enough to be reliable at least through early adolescence.

The growth curves of each of over forty measurements and combinations of measurements were plotted for each of the nine girls between the ages of eleven and nineteen. An examination of these curves, most

First Metacarpal



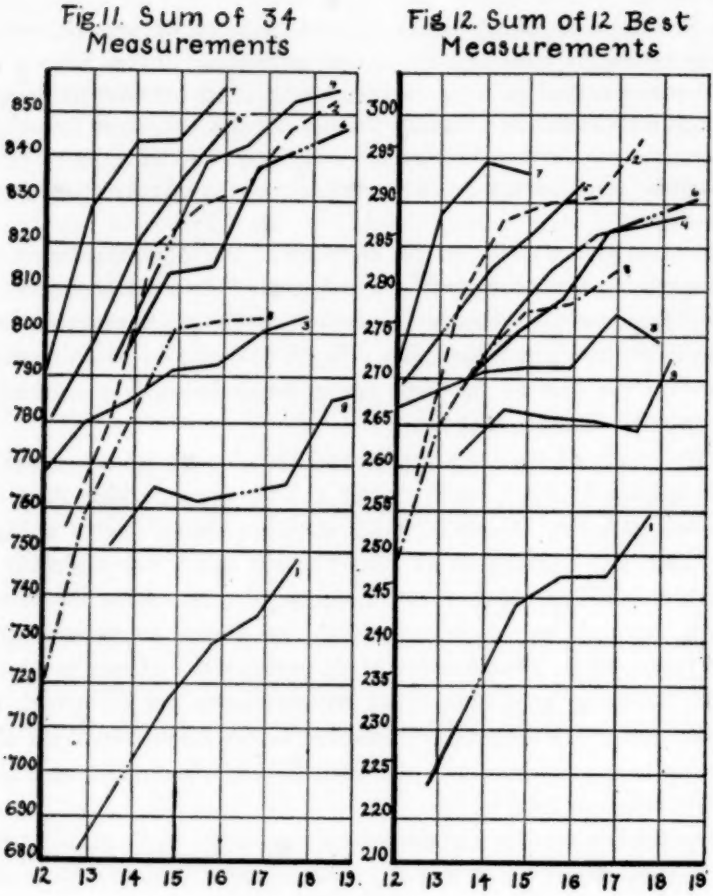
of which have been omitted here on account of lack of space, gives a good indication of which bones showed evidence of growth over the longest period of time and the actual measuring of the several individual series served as a test to determine which measurements could be made with sufficient accuracy throughout the period of growth. A number of bony landmarks that are clear in a child of eight or ten are later almost impossible to locate on account of the increased overlapping of the bones.

A casual glance at the curves of many of the individual bones gives the impression that if growth is taking place it has not been measured accurately; note for example the curves of the separate carpal bones shown in Figures 2 to 6 inclusive. Figure 7, however, which shows the curves for the sum of the eight carpal bones indicates a marked and fairly regular increase with age.

The length of the metacarpals and the breadth of the upper and lower epiphyses give growth curves a little more regular than those of the carpal bones. Those for the first metacarpal are shown in Figures 8, 9, and 10. Almost every measurement tried out indicated that growth was taking place, in the majority of girls, up to the time the records stopped, but, as stated above, the annual increments are so small that a single measurement is not sufficiently accurate to be relied upon. When a large number of measurements are combined, more reliable results are obtained. Figure 11 shows curves based on all the measurements tried out, with the exception of those that were clearly of little value—a total of 34.

The criteria for the selection of measurements to be included in the final battery were: First, that the measurements could be made objectively; second, that they were little influenced by small changes in the position of the hand; third, that the bones measured showed a prolonged period of growth; and fourth, that the combination of measurements should give an approximately equal weight to the short bones, the long bones, and the epiphysis.

The following combination of twelve measurements appeared best to fulfill the above criteria: (1) the widest diameter of five of the carpal bones, the capitate, the triangulate, lunate, navicular and greater multangular; (2) the length of the first and fifth metacarpals; (3) the broadest width of the epiphysis of the first and fifth metacarpals;



(4) the broadest width at the distal end of the first metacarpal and the proximal end of the fifth metacarpal shaft; (5) the widest diameter of the radial epiphysis.

Figure 12 shows the nine individual growth curves for the sum of the twelve measurements included in the proposed battery. A comparison of these curves with those in Figure 11 for the total of 34 measurements shows that the larger number gives somewhat smoother growth curves, as would be expected. The 34 measurements, however, require a forbidding amount of time to make and include several which were difficult to measure, but which proved to be good after they had

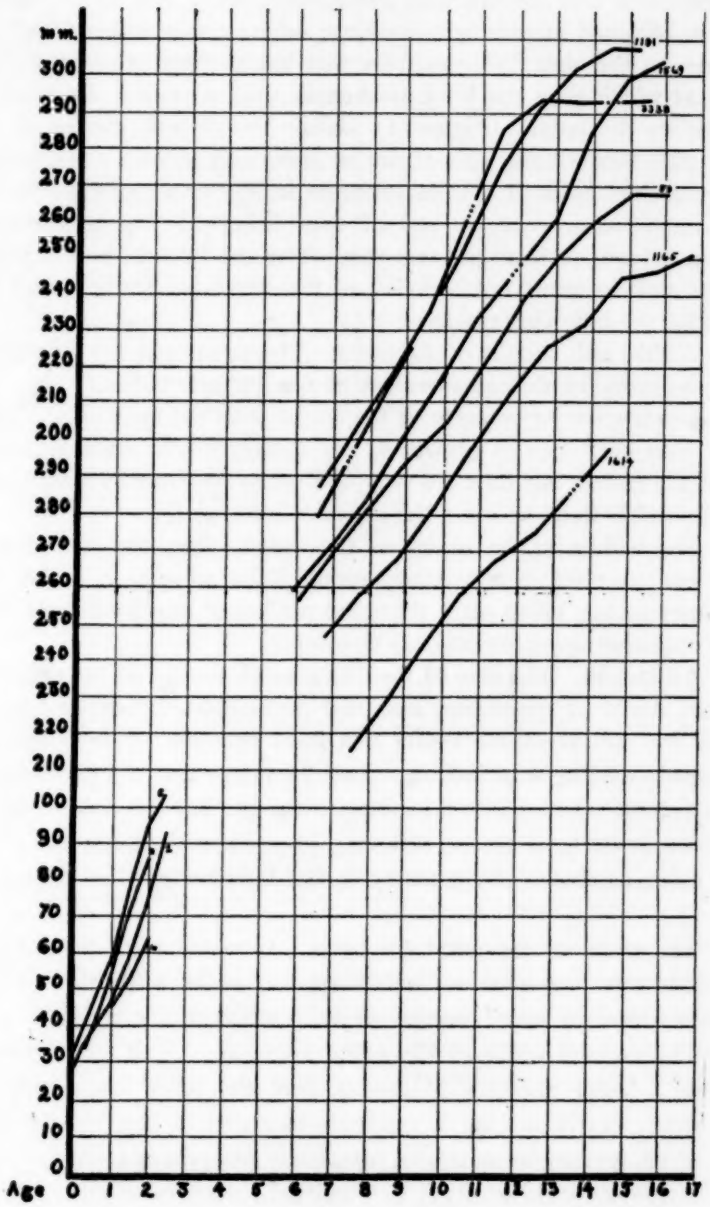


FIG. 13. INDIVIDUAL OSSIFICATION CURVES

been measured and checked with considerably more care than probably could be obtained in routine measuring; others are included which are good up to the time the epiphyses and shafts have completed their union, at which time the bony landmarks used as points from which to measure disappear. Figure 13 shows the growth curves of six school girls between the ages of six or seven and sixteen or seventeen, selected on the basis of a wide variation in size as determined by anthropometric measurements, and of four infants (random selection) between the ages of birth and two years from the Infant Growth Study.

The measurements not included in the suggested battery were excluded for the following reasons:

1. Widths and lengths of the wrist. The same field can be covered more accurately by the measurement of the separate bones.

2. The amount of contacts of the shafts with the epiphyses. These are as good indicators of growth as any measurements made, especially that of the radius, but they are very difficult to measure accurately, and it is impossible to do so when the negative is not clear.

3. The widths of the shafts of the radius, ulna, and metacarpals. These are also good, comparatively speaking, but as soon as fusion with the epiphyses has taken place there are no longer any landmarks from which objective measurements can be made.

4. All indices. The sum of the distances of contact of the epiphyses with the shafts of the radius, ulna and first metacarpal divided by the sum of the widths of the shafts is a good example of the difficulties met with in dealing with indices. Both the numerator and denominator of the fraction show marked increase with age, but the index goes up and down in the most erratic fashion. (See Figures 14, 15, 16. Prescott's index as shown in Figure 17, is but little better after the age of twelve.)

5. The width of the ulnar epiphysis. It would seem more logical to include this measurement, but it appears to be affected to a considerable extent by small changes in the position of the wrist.

6. The vertical width of the radial epiphysis. This gave evidence of being a better indicator of growth than any other single measurement and it can be accurately made up to a certain age, but the point from which it must be measured completely disappears after the union of the epiphysis with the shaft is completed, which takes place between the ages of seventeen and eighteen in most girls.

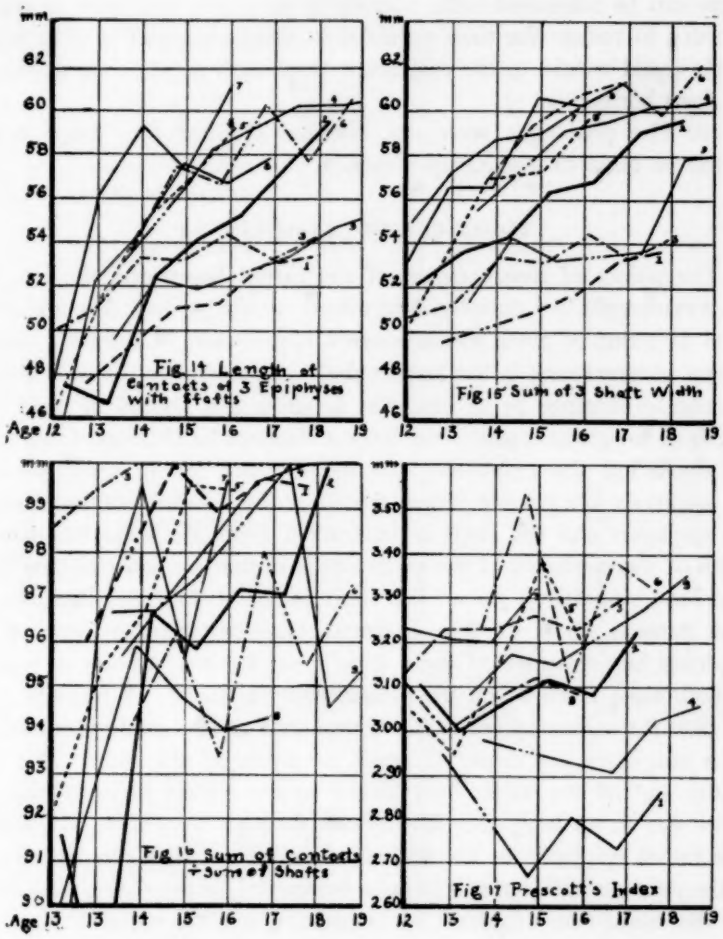


Fig 14 Length of Contacts of 3 Epiphyses with Shafts
Fig 15 Sum of 3 Shaft Width
Fig 16 Sum of Contacts + Sum of Shafts
Fig 17 Prescott's Index
Age 12 13 14 15 16 17 18 19

7. The pisiform and lesser multangular. These two carpal bones were eliminated on account of the difficulty of obtaining accurate measurements in older children. The growth curves of the sum of the carpals were slightly improved by the exclusion of the two bones most difficult to measure.

8. The interosseous distances. These are markedly affected by slight changes in the position of the hand.

9. The length of the shafts and the width of the upper and lower epiphyses of the three middle metacarpals and the hamite. All these

bones can be measured with reasonable accuracy, but were eliminated in order to reduce the time required in measuring and to give a more nearly equal weight to the epiphyses, the length of the long bones, and the short bones.

10. The phalanges were not considered since they were not included on most of the X-ray plates.

TECHNIQUE OF MEASUREMENT

The points of measurement of the carpal bones and the length of the metacarpals are entirely determined by the widest diameter. The usual direction of these measurements is indicated in Figure 1, but the correct measurement is the largest that can be obtained, and if a larger one can be obtained by shifting the direction this should be done. The length of the metacarpals is the largest that can be obtained from end to end including the epiphysis. In infants and young children where the epiphysis has not yet joined the shaft the shortest distance between the epiphysis and the shaft is subtracted from the total length. The width of the epiphyses of the metacarpals in the younger children before they have completely joined the shaft is the widest measurement. In older persons where the line of demarkation between the shaft and the epiphysis has disappeared there is in most cases a definite prominence on both sides from which the measurement is taken. When this is not the case the measurement is the widest that can be made perpendicular to an imaginary line drawn through the center of the bone. The width of the end of the metacarpal shafts is the widest measurement perpendicular to an imaginary line drawn through the center of the bone. The radial epiphysis is the widest measurement that can be obtained. In the younger children it is usually horizontal, in the older, diagonal.

The usual time required for measuring a plate varies from two to ten minutes according to the age of the child and the sharpness of the plate.

RELIABILITY

For the determination of the reliability of the measurements there were available for study X-ray plates from forty-four school girls aged ten years five months to eleven years eleven months who had had two X-ray plates of the same hand taken on the same day. Both sets of films were measured independently by two of the regular Growth Study

TABLE 1

TABLE 1

Median Differences in the Measurements Made of the Same Bones by Two Different Observers

	1st Metacarpal Length	5th Metacarpal Length	1st Metacarpal Shaft Width	1st Metacarpal Epiphysis Width	5th Metacarpal Epiphysis Width	5th Metacarpal Shaft Width	Greater Multangular	Capitate	Triangular	Lunate	Navicular	Radial Epiphysis Width	Sum of Twelve Measurements	Total
"A" vs. "B" Same Film Signs Disregarded	.11	.09	.17	.10	.11	.15	.12	.12	.12	.10	.18	.17	1.07	.13
"A" vs. "B" Same Film Signs Considered	−.04	−.08	−.14	−.01	−.02	−.06	+.03	−.06	−.01	−.02	−.12	−.03	−.28	−.04
"A" vs. "A" Different Films Signs Disregarded	.16	.21	.22	.18	.17	.20	.23	.25	.21	.13	.26	.30	.85	.21
"B" vs. "B" Different Films Signs Disregarded	.24	.24	.19	.25	.20	.17	.23	.23	.15	.18	.25	.38	1.30	.22
Different Films Checked Measurements Signs Disregarded	.21	.22	.19	.19	.24	.16	.20	.22	.15	.16	.23	.32	.98	.19

measurers, and in those cases where the measurements of the two observers differed by more than .5 of a millimeter a third measurement was obtained. A checked measurement for the purposes of this study is the average of two independent measurements, which, if they originally differed by more than .5 of a millimeter have been remeasured and that one which was in error corrected.

The errors that could be attributed to variations within the negative were insignificant. They were seldom more than .2 or .3 millimeters; in no case did the measurement of the same bone in the two plates differ by as much as 2 millimeters, and in only one per cent by over 1 millimeter. In the few cases where a difference as large as 1 millimeter was caused by a difference in the position of the hand it was found in one bone only, i.e., all the bones in the negative were not affected in the same way.

All the twelve bones included in the battery can be measured with approximately equal accuracy. The median differences between the measurements of two observers made on the same plate and on different plates of the same child taken on the same day are given in Table 1. These small differences and the high correlation coefficients (averaging above .99 when misreadings are eliminated) given in Table 2 are evidence of the high reliability of the measurements. The difference between the correlation coefficients of the checked and the unchecked

TABLE 2

Reliability Coefficients

	RHO
Checked Measurements—Different Films.....	.993 ± .002
A vs. B—Same Film.....	.964 ± .007
Misreadings eliminated	.992 ± .002
A vs. B—Different Films.....	.967 ± .007
Misreadings eliminated	.992 ± .002
A vs. A—Different Films.....	.991 ± .002
B vs. B—Different Films.....	.953 ± .010
Misreadings eliminated	.993 ± .002

measurements is so small that at first sight checking appears unnecessary, but an error of 5 or 10 in reading the scale is so common even among the more careful measurers that it appears important that these errors should be eliminated when the measurements are to be used for the study of individual development. Measurer A made the 1,056 measurements without a single misreading large enough to be recognized as such. Measurer B, on the other hand, whose measurements were otherwise almost equally exact, made eleven misreadings of 10 millimeters and one of 5 millimeters. One misreading in a hundred measurements is perhaps not more than one must expect, but as 10 millimeters at the age when growth is beginning to slow up may be equivalent to six or more months of growth it is important that such errors be located and corrected when the measurements are to be used for the study of individual growth or diagnosis. The measurements made on the two sets of plates by measurerer B correlated to the extent of .953, but when those cases which contained misreadings of 10 mm. were eliminated the correlation rose to .992. The two sets of measurements made by A correlated to the extent of .991, and the checked measurements correlated to the extent of .993.

The average difference of the checked measurements made on different plates was a little over one per cent of the measurement of each bone; there was no difference as great as 2 millimeters and only two as large as 1.5 millimeters. The median of the differences of the sums of the twelve selected measurements made on the two plates taken on the same day was 0.9 millimeters. The greatest difference in the sums was 3.3 millimeters, or one and one half per cent of the sum of the measurements. In only three cases was the difference as large as one per cent.

NORMS

Tentative norms for unselected girls are given in Table 3. But as stated above, these are probably of little value except for individuals of average size unless the amount of deviation from the norm is taken into account. Though no index appears to be practicable it is still evident that an unmodified sum of measurements does not give a satisfactory picture of development, since large bones are not necessarily an indication of advanced development or small bones of retarded development. A large child usually has large bones, but he is not necessarily above average in his stage of maturity. The sum of the measurements of

TABLE 3

Median and Quartile Points of Ossification Sums by Ages

Infants

AGE	NO.	MEDIAN
1 to 14 days	35	29.8
0-3	30	27.3
0-6	19	44.1
0-9	18	49.7
1-0	41	54.4
1-6	21	69.5
2-0	15	83.7

School Children

AGE	NO.	Q_1	MEDIAN	Q_3
5-9	42	143.8	155.0	163.1
6-6	276	151.8	165.8	175.7
7-6	142	166.7	178.6	188.1
8-6	152	184.6	194.2	203.1
9-6	316	200.8	209.3	219.9
10-6	132	214.4	225.0	238.3
11-6	122	229.0	239.2	251.9
12-6	182	248.3	260.0	273.1
13-6	265	263.1	275.1	285.4
14-6	374	271.9	281.2	290.2
15-6	288	276.8	286.1	294.4
16-6	165	278.4	285.9	294.2
17-6	55	278.8	286.5	293.8

the bones of the hand shown in B of Figure 1, for example, is slightly greater (183.6 mm.) than that of A (180.1 mm.) though the bones in A can be seen by their form and compactness to be more mature than those in B. It seemed possible that a size-ossification table, somewhat after the fashion of the height-weight tables, might be a solution and that anthropometric measurements might serve as an indication of size.

Height and the diameter of the iliac are the two measurements available which appear to give the best indication of bony size. The height is consistently, on the average, approximately six times the width of the iliac, from birth to maturity. Table 4 gives the median height divided by the median iliac diameter up to the age of sixteen.

TABLE 4

Ratio of Height to Iliac

The Number of Infants Varies From 18 to 36, the Number of School Children From 225 to 764

AGE	BOYS	GIRLS	AGE	BOYS	GIRLS
Birth	6.3	6.2	4-6	5.8	5.8
2 weeks	6.4	6.5	5-6	5.7	5.9
3 months	5.9	5.9	6-6	5.8	6.0
6 months	5.9	5.9	7-6	6.1	6.0
9 months	5.9	5.9	8-6	6.1	6.1
1 year	6.1	5.8	9-6	6.1	6.1
1½ years	6.3	6.1	10-6	6.2	6.1
2 years	6.1	6.0	11-6	6.2	6.1
			12-6	6.2	6.1
			13-6	6.2	6.0
			14-6	6.3	5.9
			15-6	6.3	5.9

There are, of course, greater individual variations. Among forty-five twelve-year-old girls, for example, there was one child with a height 6.5 times the iliac and another in which the ratio was only 5.2.

The height multiplied by the diameter of the iliac was selected as a measure of size, largely because it gave bony measurements in two dimensions and because of the constant ratio, on the average, between the height and the width of the iliac throughout the period of growth.

The ages 6, 9, 12, 13, 14, 15 and 16 were selected as sample ages on which to demonstrate the effect of size on the amount of ossified area in the wrist and hand. The height of each girl was multiplied by the width of her iliac. Then each age group was divided into three parts according to the size of the height multiplied by the iliac diameter. The upper quarter of each age group was set aside as a group of large girls, the lower quarter as a group of small girls, and the middle half as a group of medium sized girls. The median, the upper, and the lower quartile points were calculated for each of the groups for each of the sample ages.

The line running near the center of the upper lightly shaded area in Figure 18 is the median of the sums of the osseous measurements of the group of large girls while the boundaries of this shaded portion repre-

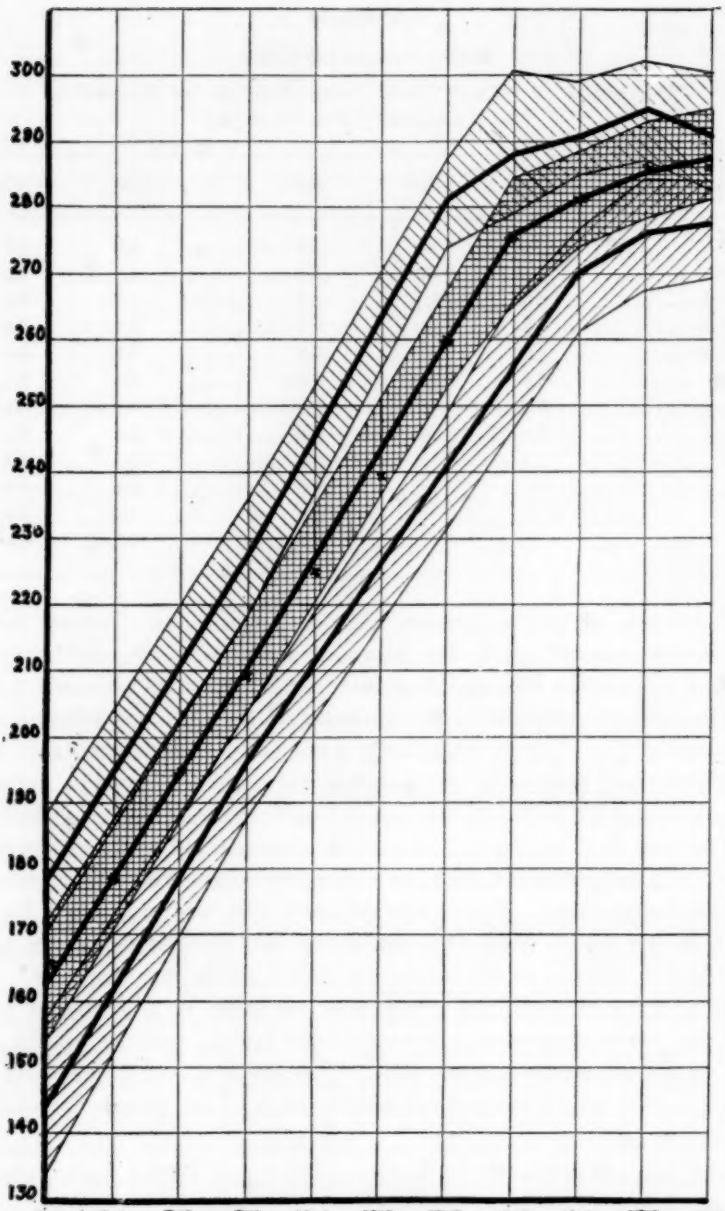


Fig. 18 Ossification in Relation to Age and Size

sent the upper and lower quartile points. The lower lightly shaded portion indicates the median and the upper and lower quartile points of the small girls. The more heavily shaded portion in the center gives the same data for those who were near average in size, and the small crosses, the medians for all the cases without regard to size.

Up to the age of twelve the upper quartile points of the group of small girls run close to the lower quartile points of the middle group while the upper quartile points of the middle group run near the lower quartile points of the group of large girls. After twelve the lower quartile points of the large girls tend to approach the medians of the middle group and about one year later the upper quartile points of the small girls cross the lower quartile points of the average sized girls and tend to approach the medians of the middle group. These data indicate a slowing up of growth from one to two years earlier for the large than for the small girls. Variation in the rate of growth will be analyzed further in a forthcoming study by Elmer D. West. The important point for the present study is to note that while there is a tendency for the large and small girls to converge at maturity, they do not meet and therefore that the stage of ossification of an unusually large or an unusually small child cannot be judged from norms based on average or unselected groups of children.[4]

The norms given are tentative and for girls only. Within a year or two norms based on adequate numbers for both boys and girls will be available. However, the regularity with which the curves rise with age makes it appear probable that the final norms for girls will not differ greatly from those presented here, though it appears probable that it will be desirable to make a finer size classification.

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[4] This process was repeated, using height divided by six added to the diameter of the iliac as a measure of size. The curves obtained are almost identical with those given in Figure 18.

ANTHROPOMETRIC STANDARDS FOR WORKING WOMEN*

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AIMS

THIS study was undertaken in order to establish a standard for build in normal women comparable to an average hospital and clinic population, so that later measurements of build in disease might fairly be compared with these normals. Since sound standards are an indispensable prerequisite to the determination of the abnormal in build or in growth, it was important to gather a group of normals in whom as nearly as possible all factors had been considered which could appear as variables in any disease group which might subsequently be studied.

MATERIAL

Criteria for selection.—Accordingly, we planned to measure 100 women who would be homogeneous in the following respects:

1. Economic Status: working women
2. Age: 20-60 years
3. Northwest European stock
4. Health:
   (a) no history or evidence of past or present disease thought to be related to build,
   (b) good health in the past year,
   (c) normal menstrual history.
5. Weight: within 15 per cent of the predicted weight by the Medico-Actuarial tables; and with no history of obesity at any age nor of large weight fluctuations.

*We are indebted to a grant from the Rockefeller Fluid Research Fund.

The procedure was to inquire first concerning age, then ancestry, then health, and lastly to make a rough calculation of normality of weight on the basis of the patient's statements of weight, height and age. If these preliminaries were satisfactory, the complete examination was undertaken. But suggestive physical signs in the course of the anthropometric procedures, especially the exact determinations of height and weight, often threw out subjects tentatively accepted. At least five women were interviewed for every one finally included. Slight concessions, where consideration of all factors warranted the assumption that they were negligible, were sometimes made, in order that the time of getting the group together should not be too greatly prolonged. We shall give, therefore, both our reasons for these five requirements and an analysis of what proved to be their actual interpretation.

Economic Status.—Since financial position has a bearing on growth and development and probably on build, selection was made to secure a group similar to that of our clinic patients. This meant "working women," not in the sense of being gainfully employed, but simply in the sense of being women who worked, whether in the home or outside of it. The leisure class was excluded.

The main source of material was the "Women's Division of the San Francisco Citizens' Committee for Unemployment Relief." Through the coöperation of the director, Miss Winifred Pearce, it was possible to measure 87 women at the Committee headquarters during the months of April and May, 1932. The remaining women were collected: 9 from the various staffs of the Stanford University Hospital, and 4 from miscellaneous sources.

The nature of employment was as follows:

House, hotel, restaurant, practical nursing....	33
Commercial (mercantile and office).....	29
Professional and Student	18
Light Trades	16
Not Stated	4
	100

The marital status was: married 58, single 36, not stated 6.

Age.—Using the exact birth date, age was calculated to years and months, and then rounded to the year at the nearest, not the last, birthday. The limits of 20-60 were chosen so that subjects should be old

enough to have reached their mature build, and not so old as to have begun to deteriorate. Also, since certain measurements like weight and chest girth are known to vary with age, it was desired to have a fairly regular distribution over the age range. That this was in fact achieved is evidenced by the following age frequency distribution:

Age	*20 and under 30*	*30—*	*40—*	*50—*	*Total*
Frequency ...	30	30	27	13	100

The mean age was 36.2 years $\pm$ 0.70; $\sigma = 10.34 \pm 0.49$; CV = 28.53.

Race.—Since the racial stock of our hospital patients is predominately Northwest European, we attempted to limit these controls to the same stock. No Jews were included. Each subject was asked the birthplace of herself, father, mother, father's father, father's mother, mother's father, mother's mother. Where these were not known, the racial strain to the best of the subject's knowledge was recorded. By Northwest European we mean: Northwest European countries, namely United States of America, Austria, British Isles, Canada, Denmark, France, Germany, Holland, Norway, Russia (Caucasus), Sweden; and by "other" we mean Bohemia, Bulgaria, Spain. The resulting birthplaces were:

	N.W.E.	*Other*	*Not Known*	*Totals*
Subject	100	..	..	100
Parents	197	3	..	200
Grandparents	354	11	35	400

Of the 35 grandparents whose birthplaces are tabulated as "Not Known," 32 were reported as of Northwest European stock, and 3 of Spanish stock. The racial origin, i.e., the stock of the grandparents of the 7 women with any admixture of blood other than Northwest European, was as follows: 4 Bulgarian grandparents (subject No. 84), 4 Polish (No. 20), 1 Bohemian (No. 68), 2 Spanish (Nos. 24, 57, 73), 1 Spanish (No. 51).

In summary then, it can be said that our series comprised:

93 women of Northwest European stock, including 20 Old Americans (all 4 grandparents American born) and 13 first generation immigrants,

5 of Northwest European stock with an admixture of either one-half or one-quarter Spanish or Slavic blood,
1 full-blooded Slav,
1 full-blooded Pole.

Health.—Some conditions which have no expected relation to build were accepted as compatible with our health requirements: tonsillectomies, appendectomies, certain other surgical episodes, bad teeth. If we had attempted to exclude them, it would have been surprisingly difficult to find our normals. The operations recorded were: appendectomies 18 (3 with salpingectomies), tonsillectomies 15, pelvic operations other than the above salpingectomies 3, Caesarean 1, minor operations 5.

Good health in the past year was demanded so that we might have a group of at least nominally "well" women. Some subjects were excluded for minor illnesses such as frequent colds, because these, though not influencing bony measurements, might possibly have affected girths, which interest us mainly as measures of subcutaneous tissues.

Menstruation is so variable a phenomenon that normal has an even broader meaning than usual in describing it (Fluhmann). More precisely, no one with a definitely abnormal history was included: i.e., no history of amenorrhea or metrorrhagia; nor of such constitutional or endocrine symptoms as are attributable to pelvic disease.

The ages at menarche and at menopause were likewise recorded, though these statements we believe unreliable in persons whose catamenia are normal. However, the questions served the purpose of excluding the abnormals, by whom the facts are more definitely recalled. The mean age of the menarche was 13.6 ± 0.1 years, and among the 26 women who were either definitely undergoing the menopause or whose menses had already stopped, the mean age of the climacteric was 43.5 ± 0.6 years.

Weight.—A few words may be said concerning the exclusion of subjects on the basis of one of the most important measures of build, i.e., weight. The *a priori* decision to limit our subjects to those falling within 15 per cent on either side of the Medico-Actuarial tables was made partly as a matter of convenience, since we propose later to investigate the bony structure of those who deviate further than this from the normal; and partly because these borders have frequently been taken as clinical concepts of "normal weight." These tables are based on measurements with clothing. The calculations for our purposes

were made by the following routine corrections: 2 inches were added to the heights taken without shoes, the predicted weight for age was then located on the table; 4 pounds were subtracted from this to give a predicted net weight with which to compare the measured net weight.

It was on the same basis of clinical concepts that women were excluded who had had any marked weight fluctuations. The arbitrary nature of minus 15 per cent as a lower limit was evidenced by the exclusion of three women who were between 15 and 20 per cent underweight although acceptable on every other basis. The upper border of plus 15 per cent, however, was, when exceeded, always accompanied by some other suggestion of disorder. Our weight distribution, therefore, represents a random sample only among a particular group which to the eye of the medical examiner seemed definitely normal and against which border line cases could later be placed.

ANTHROPOMETRIC TECHNIQUE

Observer.—All measurements made by the same observer (L.M.B.), and dictated to the same secretary.

Clothing.—None, or light silk drawers, which were shifted as necessary. Measurements are, therefore, all net.

Anthropological Instruments and Measurements.—The instruments used and measurements made were those recommended and discussed by Gray and Ayres in 1931, with the addition of a few circumferences. The measurements followed the International Agreements of Monaco in 1906 and of Geneva in 1912 as reported and annotated by Hrdlička, together with more detailed directions in his own *Anthropometry,* and a few modifications as specified. The measurements and their symbols are listed in the tables of constants following.

Circumferences.—The technique of the circumferences used is outlined briefly, since these are not detailed in the book referred to. They were taken with linen tape, standardized from time to time against a metal scale.

Trochanter (Tr).—With the subject standing with knees together, and feet together and parallel, the tape is placed over the pubic region, the trochanters and the greatest bulge of the buttocks (Martin, 1928, p. 169).

Thigh (Tg).—Left, subject standing with weight on right leg. Measurement taken with tape horizontal at the level of the gluteal fold.

Calf (Cf).—Left, same position; maximum reading.

Upper Arm (UA).—Left, arm relaxed; maximum reading below deltoid insertion.

Fore Arm (FA).—Left, arm relaxed; measurement immediately below joint level, i.e., maximum.

Calculated Values.—From the above data were calculated on each subject: modules, relative measurements, and indices as indicated in the tables.

In addition to these measurements five other hand and wrist measurements and a hand contour were recorded for each subject. These will be worked up and reported separately.

STATISTICAL METHODS

Number of Subjects.—Since this was a carefully selected group, the number of 100 is considered to reconcile fairly well the demands of statistical reliability with the limitations of time in practical work, as discussed recently at some length by Gray and Ayres.

Calculation of Constants.—The same book likewise discusses in detail the mechanical and technical aspects of handling the raw data, and the detailed procedure for the calculation of constants.

In summary, the steps were as follows, each process being checked, and all being done with the help of tables or calculating machine.

On each record sheet were calculated the modules, relative measurements and the indices.

Original and derived measurements were transferred to two "80 column" punch cards for each subject.

A frequency distribution was then made for each measurement by means of a sorting machine. These frequencies were then grouped in 12 or more class intervals on frequency sheets. For each measurement was then calculated, directly on the sheet in space provided; mean and probable error, standard deviation and probable error, and coefficient of variation. The resulting basal data are shown on the left in two Tables of Constants with a deviation chart for the first (Fig. 1). This exhibits the constants in graphic form, with an absolute scale to permit plotting of the measurements as obtained on any individual, and simultaneously a deviation scale to facilitate judgment of the position of the individual with regard to her controls. For the theory of this chart, see Gray and Ayres, 1931.

TABLE 1

TABLE OF CONSTANTS

AGE 36.2 YEARS (20-59) N = 100

Working Women N.W.E. Stock Diagnoses: Normal

Measurements: Metric & Without Clothing

MEASUREMENT		MEAN ± PE		SD ± PE		CV
Weight in k.	W	61.48	.49	7.27	.35	11.82
Stature in mm.	S	1615.45	4.17	61.77	3.95	3.82
Sitting height	Si	855.05	1.97	29.23	1.39	3.42
Chest Circumf.	C	858.85	3.66	54.30	2.59	6.32
Trans.	T	275.65	1.27	18.86	.90	6.84
Ant.post.	AP	205.90	1.24	18.39	.88	8.93
Module	ChM	240.60	1.14	16.90	.81	7.02
Shoulder Biacromial	BA	355.45	.92	13.67	.65	3.85
Pelvis Bicristal	BC	301.15	1.09	16.11	.77	5.35
Head Length	L	186.76	.40	5.89	.28	3.15
Breadth	B	148.78	.29	4.30	.21	2.89
Height	OH	120.06	.29	4.30	.21	3.52
Module	CM	152.00	.25	3.70	.18	2.43
Face Height	MN	114.10	.42	6.17	.29	5.41
Breadth	BZ	133.00	.29	4.24	.20	3.19
Module	FM	123.87	.27	4.02	.19	3.25
Nose Height	NH	52.20	.21	3.10	.15	5.94
Breadth	NB	33.57	.16	2.41	.11	7.18
Above-named measurements in percent of Stature	W/S	37.94	.25	3.75	1.79	9.88
	Si/S	52.99	.09	1.30	.06	2.45
	C/S	53.15	.22	3.32	1.58	6.25
	T/S	17.06	.07	1.10	.05	6.45
	AP/S	12.72	.07	1.11	.05	8.73
	ChM/S	14.89	.07	1.00	.05	6.72
	BA/S	22.02	.06	.89	.04	4.04
	BC/S	18.65	.06	.94	.04	5.04
	L/S	11.58	.03	.49	.02	4.23
	B/S	9.23	.03	.40	.02	4.33
	OH/S	7.45	.02	.35	.02	4.70
	CM/S	9.42	.02	.37	.02	3.93
	MN/S	7.08	.03	.39	.02	5.51
	BZ/S	8.24	.02	.35	.02	4.25
	FM/S	7.68	.02	.29	.01	3.78
	NH/S	3.23	.01	.21	.01	6.50
	NB/S	2.07	.01	.16	.01	7.73
Index Chest	AP/T	74.60	.35	5.21	.25	6.98
Trunkbreadth	BC/BA	84.86	.33	4.88	.23	5.75
Cephalic	B/L	79.70	.18	2.72	.13	3.41
Facial	MN/BZ	85.89	.26	3.79	.18	4.41
Face/Head L	MN/L	61.23	.24	3.59	.17	5.86
Face/Head B	BZ/B	89.47	.17	2.48	.12	2.77
Nasal	NB/NH	64.63	.40	5.88	.28	9.10

Deviation Chart — 100 Normal Women Age 20-59		−3σ	−2σ	−1σ	M	+1σ	+2σ	+3σ
Weight in k.	W	40	50	60		70		80
Stature in cm.	S		150	160		170		180
Sitting height	Si		80	85		90		
Chest Circumf.	C	70	80		90			100
Trans.	T	23	25	27	29	31		33
Ant.post.	AP	16	18	20	22	24		26
Module	ChM	20	22	24		26		28
Shoulder	BA		33	35		37		39
Pelvis	BC	26	28	30		32		34
Head Length	L	17	18	19			20	
Breadth	B	14			15			16
Height	OH	11		12			13	
Module	CM		14·5	15·0	15·5		16·0	
Face Height	MN	10		11	12		13	
Breadth	BZ		12·5	13·0	13·5	14·0		14·5
Module	FM	11·5		12·0	12·5	13·0		13·5
Nose Height	NH	4·5		5·0	5·5		6·0	
Breadth	NB		3·0		3·5		4·0	
Above-named measurements in per cent of Stature	W/S	30		35	40	45		
	Si/S	50		52	54		56	
	C/S	45		50	55		60	
	T/S	14	15	16 17	18	19	20	
	AP/S	10	11	12	13	14	15 16	
	OH/S	12	13	14	15	16	17	
	BA/S	20	21	23		23	24	
	BC/S	16	17	18	19	20	21	
	L/S		11		12		13	
	B/S		8·5	9·0	9·5	10·0		
	OH/S	6·5	7·0		7·5	8·0		8·5
	CM/S	8·5	9·0		9·5	10·0		10·5
	MN/S	6·0	6·5	7·0		7·5	8·0	
	BZ/S	7·5		8·0	8·5		9·0	
	FM/S	7·0		7·5		8·0	8·5	
	NH/S	2·6 2·8	3·0	3·2	3·4	3·6	3·8	
	NB/S	1·6	1·8	2·0	2·2		2·4	
Index Chest	W/C	60		70		80		90
Trunkbreadth	BC/BA	75	80	85		90	95	
Cephalic	B/L		75		80		85	
Facial	MN/BZ	75	80	85		90	95	
Face/Head L	MN/L		55	60		65	70	
Face/Head B	BZ/B		85		90		95	
Nasal	NB/NH	50		60	70		80	

FIG. 1. DEVIATION CHART

TABLE 2

TABLE OF CONSTANTS

AGE 36.2 YEARS (20-59) N=100

Working Women N.W.E. Stock Diagnoses: Normal

Measurements: Metric & Without Clothing

MEASUREMENT		MEAN ± PE		SD ± PE		CV
Circ. Waist	Wst	732.15	4.81	71.37	3.40	9.75
Troch.	Tr	997.65	3.21	47.58	2.27	4.77
Thigh	Tg	568.35	2.29	33.88	1.62	5.96
Calf	Cf	343.50	1.26	18.73	.89	5.45
U. Arm	UA	284.85	1.64	24.35	1.16	8.55
F. Arm	FA	240.10	.88	13.09	.62	5.45
Above-named measurements in per cent of Stature	Wst/S	45.75	.27	3.97	.19	8.68
	Tr/S	61.89	.18	2.65	.13	4.28
	Tg/S	35.23	.13	1.92	.09	5.45
	Cf/S	21.27	.08	1.15	.05	5.41
	UA/S	17.67	.10	1.49	.07	8.43
	FA/S	14.86	.06	.83	.04	5.59

COMPARISON WITH OTHER SERIES

Observers.—In order to evaluate our constants, we have compared them with five other American series. Our special interest in each of the authors chosen was as follows:

Draper: Hospital material of comparable social economic level, though a pool of disease groups.

Hrdlička: Age range and racial stock comparable with ours.

Todd: Social-economic level comparable or inferior to our own, offering a contrast to the college and Old American groups.

Wilder and Pfeiffer: Data on practically the same measurements which we used; *N* of 100 so that the standard deviations and probable errors are comparable with ours; racial stock similar.

Steggerda *et al*: More recent material than Wilder and Pfeiffer, but otherwise so similar that a consideration of the differences in their two sets of means should give some practical idea of the significance of our differences from these and other series, aside from the conventional statistical judgments in such matters.

Standardization.—The results of these observers, for purposes of uniform comparison, required some adjustments. Those we have ventured to apply were as follows:

1. Measurements taken with clothing were converted to net measurements either according to the author's directions, or where these were lacking, according to appropriate directions by other authors.

2. Todd's measurements on the dead were converted wherever his directions permitted, to the most probable values on the living.

3. Measurements taken with a technique different from ours were converted to the most probable values with our own technique.

4. The relative measurements and indices were calculated for all the absolute measurements. In some cases, for some or most of the measurements this had already been done. But since in every case we calculated a few more than were originally presented, we followed the general rule of recalculating all the values. This introduced differences in that the "mean index" obtained by dividing the mean of a measurement by mean stature is not so correct as the mean of the hundred individual indices of measurement over stature. Actually the differences, where we had both values, were only slight, so that we used our calculated values throughout for the sake of uniformity. To conserve space the five adjusted series are not published, but their profiles are plotted as described below.

Deviation Charts.—So that comparisons might be made easily we drew up two deviation charts. One is the deviation chart already shown, based on the standard deviation for the distribution of each measurement (sigma scale), and is suitable for plotting ***individuals*** against our means. The other chart is based on the standard error of each mean ($\sigma/\sqrt{N}$ = epsilon scale), and is suitable for plotting the ***means*** of other groups against our mean. The theory of the standard error deviation chart is that "If a quantity be normally distributed with standard deviation σ, then the mean of a random sample of N such quantities is normally distributed with standard deviation $\sigma/\sqrt{N}$. If the difference (of an observed mean from any standard mean) is many times greater than the standard error, it is certainly significant and it is a convenient convention to take twice the standard error as the limit of significance." (Fisher).

The calculation for the standard error chart was made very simply from the tabulation of standard deviations, since with $N = 100$, the

Deviation Chart for Means	100 Normal Women Age 20-59						
	-3€	-2€	-1€	M	+1€	+2€	+3€
Weight in k. W	60.0		61.0		62.0		63.0
Stature in cm. S	160.0		161.0		162.0		163.0
Sitting height Si		85.0		86.5		86.0	
Chest Circumf. C	84.5	85.0	85.5	86.0	86.5	87.0	87.5
Trans. T	27.2		27.4	27.6	27.8		28.0
Ant post. AP	20.2	20.4	20.6		20.8	21.0	
Module ChM	23.6	23.8	24.0	24.2		24.4	
Shoulder BA	35.2	35.4		35.6		35.8	
Pelvis BC		29.8	30.0	30.2		30.4	30.6
Head Length L	18.55		18.65		18.75		18.85
Breadth B	14.80		14.85	14.90		14.95	15.00
Height OH	11.90	11.95	12.00	12.05		12.10	
Module CM	15.10	15.15	15.20		15.25		15.30
Face Height MH		11.30	11.40		11.50		
Breadth BZ	13.20	13.25	13.30		13.35	13.40	
Module FM	12.30	12.35		12.40		12.45	12.50
Nose Height NH	5.15		5.20		5.25		5.30
Breadth NB	3.30		3.35			3.40	
W/S	3.70	3.75		3.80		3.85	3.90
Si/S	52.6	52.8		53.0		53.2	
C/S		52.5	53.0		53.5		54.0
T/S	16.8		17.0		17.2		
AP/S	12.4	12.6		12.8			13.0
ChM/S	14.6		14.8		15.0		
BA/S	21.8		22.0			22.2	
BC/S	18.4		18.6		18.8		
L/S	11.45	11.50	11.55	11.60	11.65	11.70	
B/S	9.15		9.20	9.25	9.30		
OH/S	7.35	7.40		7.45	7.50		7.55
CM/S	9.35		9.40	9.45		9.50	
MH/S	7.00		7.05	7.10	7.15		
BZ/S	8.15	8.20		8.25	8.30		
FM/S	7.60	7.65		7.70		7.75	
NH/S	3.18	3.20	3.22	3.24	3.26	3.28	
NB/S		2.04	2.06	2.08	2.10		
Index Chest S/T	73.5	74.0	74.5	75.0	75.5	76.0	
Trunkbreadth B/BA	83.5	84.0	84.5	85.0	85.5	86.0	
Cephalic L/B	79.0		79.5		80.0		80.5
Facial MH/BZ	85.0	85.5		86.0	86.5		87.0
Face/HeadL MH/L	60.5		61.0	61.5		62.0	
Face/HeadB BZ/L	89.0			89.5		90.0	
Nasal NB/NH	63.0	64.0		65.0		66.0	

Above-named measurements in per cent of Stature

FIG. 2. DEVIATION CHART FOR MEANS

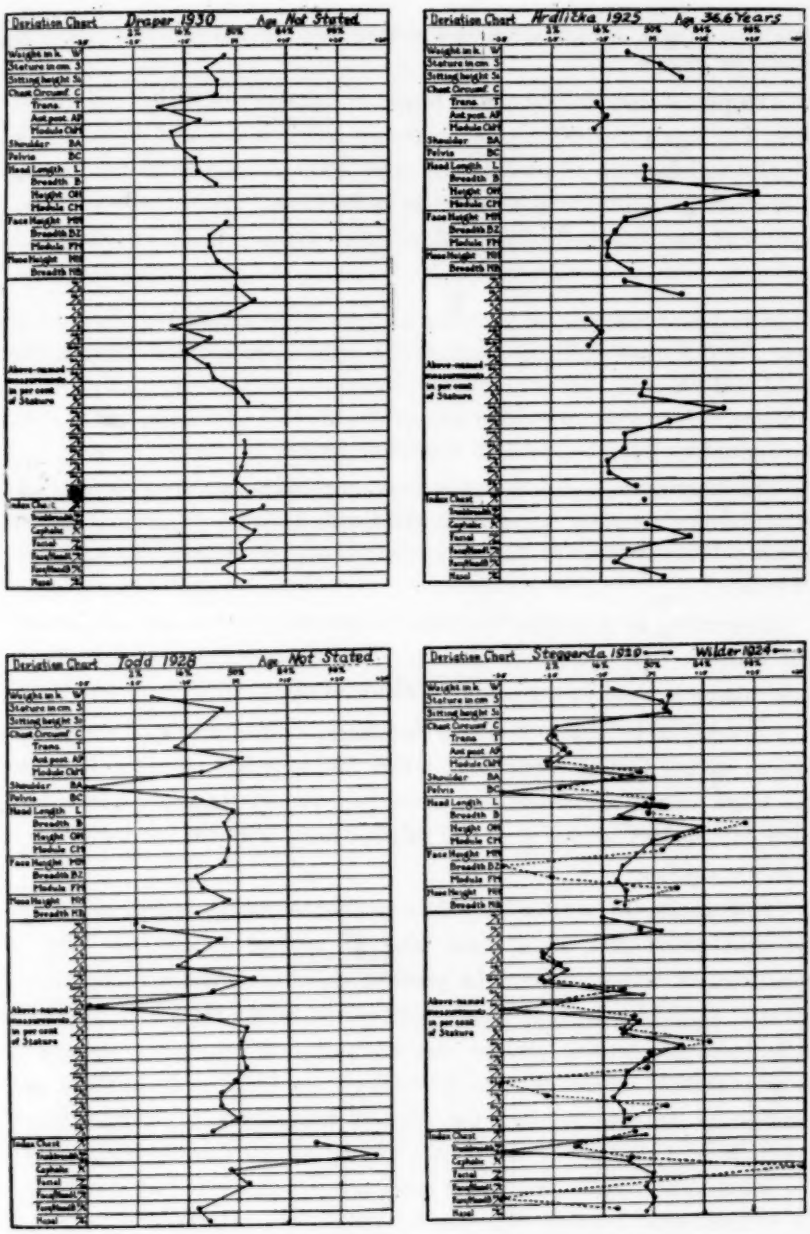
Deviation Chart Draper 1930 Age Not Stated
Deviation Chart Hrdlička 1925 Age 36.6 Years
Deviation Chart Todd 1928 Age Not Stated
Deviation Chart Steggerda 1929 Wilder 1924

FIG. 3. OTHER SERIES PLOTTED AGAINST OUR MEANS

standard error ϵ is one-tenth of the standard deviation. The chart is shown in Figure 2.

The profiles on epsilon scale, however, showed too many points off scale, i.e., too great differences between other series and ours, to be visually satisfactory. Consequently they were re-plotted on the sigma-scale charts, though these, it must be remembered, do not permit direct numerical interpretation of the differences. These profiles are shown in Figure 3.

Differences Notable in Profiles.—Concerning direct measurements, these are the more striking findings: In height our women stand above Todd and Draper, below Hrdlička, Steggerda and Wilder. In weight they are heavier than any other group. In breadth of frame (head, face, chest and hips) they exceed all the other groups.

The other groups vary not only from our series, but from each other, the only similar plots being the two Smith College groups, and even between them one notes a few extraordinary discrepancies, e.g., BC, OH, BZ.

Concerning measurements relative to stature, our women are heavier and broader than the other groups. There is less scatter in relative measurements than in the absolute observations.

Concerning indices, our group run fairly in the center of the distribution, except that the indices in which BC and BZ appear still reflect the large values we have for these two measurements. The index plots exhibit less scatter than the relative measurements, and much less than the absolute.

This matter of scatter may justify the following speculation. On the assumption that, since these were all normal groups, the type of measurement which showed the greatest stability (least scatter) among normals would be the type which later would be the most significant for differences in disease groups, an analysis was made to see which measurements: direct, relative, or indices, would give the highest percentage of agreement—i.e., the highest percentage of measurements which were within 2ϵ of our own. The results of this analysis confirm the impression of the profiles in making us anticipate that comparison of indices will be more illuminating than comparisons of absolute or even relative measurements. The analysis mentioned is shown below:

Type of Measurement	*Items*	*Actual Agreements in Per cent of Items*
Direct and Modules	83	17
Relative to Stature.....	78	27
Indices	34	41

Explanations of Above Differences.—The divergences between our group and the others may well be explained by re-consideration of our bases of selection.

1. By selecting working women, we got a group which was more heavily built than the "Old Americans," and shorter than either that or the college groups.

2. By selecting a wide adult age range, we got a group which was naturally heavier and bigger in the chest than the college groups.

3. By selecting for health, we got a group which was taller, better nourished, and more heavily built than either Draper's or Todd's collection, and this is to be expected. In his paper, Todd warns especially concerning both the pre- and postmortem factors which tend to make his cadavers underweight and in general narrow.

TABLE 3

Some Comparisons of Stature and Weight (Arranged in Order of Stature)

GROUP	N	AGE	S	W	W/S	AUTHOR
English Working Women						
Unemployed	413	20-55	152.2	49.6	32.6	Cathcart *et al.*, 1927
Factory	1,892	20-55	157.4	50.7	32.2	Cathcart *et al.*, 1927
Heavy Trades	237	19-50	159.1	53.2	33.4	Cathcart *et al.*, 1927
100 Normals	100	20-59	161.5	61.5	37.9	Our data
Other Dispensary Groups						
Pres. Hospital	331	....	157.7	59.5	37.7	Draper, 1930
Old Va. "Dispensary"	55	26-60	160.1	...	...	Bean, 1931
100 Normals	100	20-59	161.5	61.5	37.9	Our data
Miscellaneous American Groups						
Insured Women 131,099		20-59	158.2	61.0	38.6	Med. Act. Mort. Inv., 1912
100 Normals	100	20-59	161.5	61.5	37.9	Our data
Old Virginians	462	....	161.6	...	...	Bean, 1931
Stanford University	1,854	....	162.3	...	...	Mosher, 1923

4. By selecting for weight on the basis of the Medico-Actuarial tables, we may have shifted our mean to the right (heavier side) since calculated underweight was occasionally the only factor in exclusion.

5. As one's eye runs over the charts a quite reasonable explanation occurs for the relation of our own mean to each point of each author. There seems no need to go over these points individually. In general the differences of the present series from other series seem such as could be predicted on the basis of selection, and they can be reasonably enough explained to permit the assumption that they are differences of material and not of technique or calculation. Occasionally the differences of other authors from each other, as, for instance, Steggerda vs. Wilder for the items BZ, BC, and OH, suggest that other factors than selection may have entered into their figures.

Some Additional Comparisons of Stature and Weight.—A few further series giving data on height and weight, or height only, have been compiled in Table 3. In making this table the averages for the Medico-Actuarial and Cathcart data represent recalculations of only that portion of their material which fell within the age range of our own data. The insurance figures were further corrected by a subtraction of 2 inches for height and 4 pounds for clothes. That the 4 pounds weight correction is a legitimate assumption, in spite of the change in women's clothing, is shown by the fact that the Medical Impairment Studies of 1929 show weights which nowhere vary more than 3 pounds from the 1912 tables, and are usually within ± 1 pound of the original table. So that, whatever factors may have entered in, the same guess for weight of clothing seems to work for the older data as is known by tests in our own outpatient clinic to be satisfactory for the present average weight of women's clothing.

From the table it may be seen that our group is again taller, heavier, and relatively heavier than the other groups, with the following exceptions:

1. The corrected Medico-Actuarial figures, which were the bases of our weight selection, give a weight/stature ratio which is the only one bigger than our own.

2. The superiorly placed groups (Old Virginians and Stanford College women) are again taller than our women.

SUMMARY

To form a normal control group, 100 working women have been selected who were as homogenous as possible with respect to the factors of economic status, age, stock, health and weight. It is thought that these five factors include the essential variables which will later need to be considered in disease groups.

Twenty-four anthropometric measurements have been made on each subject, and relative measurements and indices calculated from these.

The observations have been reduced to the usual biometric parameters which are presented in tabular form.

From these constants have been prepared a standard deviation chart for use in placing individuals with respect to our normals, and a standard error chart for plotting other means against our own.

Five series of fairly complete anthropological measurements on American women have been compared with our own and also a few further series showing stature and weight only.

The striking divergences between these possible standards call attention to the inherent difficulty in making a statistically crucial study of build in disease. It is clear that if satisfactory conclusions are ever to be warranted, subjects must be selected for study in whom the variables have been reduced as far as possible to the sole factor of the disease diagnosis.

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THE WEIGHT OF THE ENDOCRINE GLANDS*

BIOMETRICAL STUDIES IN PSYCHIATRY, No. 8

BY WALTER FREEMAN, M. D., PH. D.

FOR many years there has been an impression, sometimes amounting to a conviction, that many mental disorders were conditioned by disturbances in the endocrine organs. Nevertheless, although numerous contributions have appeared dealing with the biochemical and therapeutic aspects of the problem, there has been little concerted attack upon the anatomical foundation. It was with a view to determining this anatomical substrate that the series of biometrical studies was undertaken in 1925, and the assembling of the material finally completed during the past year. The data are now available for analysis of the relationship of the endocrine organs to the personality, but it is thought that a preliminary report upon the mass data is warranted by the paucity of controlled observations upon the weight of these glands. This study, therefore, deals with the weight of the endocrine glands in relation to age, sex, race, body weight and stature.

In most of the previous studies great emphasis has been laid upon age, and no doubt there are marked changes in the function of various organs with increasing age, but this appears not to be reflected in the weight of the endocrine organs in the later periods of life after growth has been accomplished. Moreover, the observations at the high extremes of life are so few as to leave some doubt as to the significance of the weight changes, when the probable errors are taken into consideration.

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The biometric treatment of the data was planned and supervised by Dr. Raymond Pearl, Professor of Biology in the School of Hygiene and Public Health of The Johns Hopkins University, and carried out under his direction by Miss Marjorie Gooch, Associate in the Department of Neurology of George Washington University.

In a preliminary study average weights for the endocrine organs were calculated for individuals under 50 years and over 50 years of age. The basis for excluding the pathological organs was not the same as that used in this paper so that the relations found there are not directly transferable to the present study. On the whole, however, this preliminary study showed so little difference with age that it was not thought necessary to repeat the procedure here.

While emphasizing age changes, pathologists have largely neglected consideration of stature and body weight, two properties of the body that are apparently of great significance. Some of the tables given below, therefore, present coefficients of correlation between these functions of the body and the mass of the endocrines. Further studies may be undertaken showing the amount of influence exerted by one endocrine organ upon another, but from preliminary studies it appears that very little correlation one way or the other may be expected.

MATERIAL AND METHODS

As described in the first paper of this series (1), several measurements are carried out upon the subject before the necropsy, and then each of his organs is dissected out, freed from fatty and other tissue as far as practicable, and then weighed and measured. The glands studied in this work have all been from psychotic individuals dying in St. Elizabeth's Hospital, a Federal Institution.

The study presumes to show the mass of the normal endocrine organs. Organs significantly abnormal either grossly or microscopically have been excluded from consideration. Certain observations that were very divergent from the rest of the measurements and therefore seemed to suggest an error in the record were also omitted. Their effect upon the means is negligible on account of their very small number.

The raw data were transferred from the work sheets to 80-column statistical cards, two cards being used for each case. There was space, therefore, not only for identification, classification, and certain other clinical details, but also for the weights of the organs and for the codification of the lesions encountered in each of the major organs.

It must be borne in mind that the glands of this study are not exactly comparable with any other series of glands because of their derivation from psychotic patients, geographical distribution, personal equation as regards accuracy in weighing or trimming, and differences in age distribution.

TABLE 1

Relation of Body Weight and Stature in Material Investigated

RACE AND SEX	NUMBER	CONSTANTS	BODY WEIGHT *kilos*	STATURE *cm.*
White male	544	Mean	53.55 ± .40	170.74 ± .21
		Standard deviation	13.92 ± .28	7.15 ± .15
		Coefficient of variation	25.99 ± .57	4.19 ± .09
		Correlation coefficient	+ .340 ± .026	
Negro male	296	Mean	50.95 ± .53	169.31 ± .29
		Standard deviation	13.52 ± .37	7.52 ± .21
		Coefficient of variation	26.54 ± .79	4.44 ± .12
		Correlation coefficient	+ .392 ± .033	
White female	228	Mean	44.12 ± .71	157.43 ± .33
		Standard deviation	15.98 ± .50	7.38 ± .23
		Coefficient of variation	36.22 ± 1.28	4.69 ± .15
		Correlation coefficient	+ .336 ± .040	
Negro female	206	Mean	46.07 ± .62	158.23 ± .33
		Standard deviation	13.21 ± .44	7.02 ± .23
		Coefficient of variation	28.67 ± 1.05	4.44 ± .15
		Correlation coefficient	+ .193 ± .045	

If any striking discrepancies appear between the weight of the endocrine organs in this study and in other studies, such divergencies should be the signal for renewed attack upon the problem in an effort to elucidate the reason for such differences. It may be that the key to progress in the understanding of mental diseases may be furnished by the endocrine organs. Personally, I am doubtful whether studies on the weight of the endocrines will be of more than negative assistance, but it is distinctly possible that some personality differences in individuals may be reflected in the size of their glands of internal secretion.

The character of the necropsy material submitted to study is shown in Table 1. This study is based on 1,337 cases, of which 1,274 were complete for both weight and height. White males are slightly taller and heavier than colored males, while the reverse is true in females. The low average weights are rather striking, but the large number of aged individuals and the prevalence of wasting diseases among the insane probably account for this.

EPIPHYSIS

The epiphysis is attached to the roof of the third ventricle of the brain and is enmeshed in the meninges but is usually resected easily. It is sometimes so friable, however, that portions may be left in situ. The weight of the epiphysis is quite variable; the organ may be almost microscopic in size, but may sometimes weigh half a gram or more, and yet be entirely normal both grossly and microscopically. Only occasionally is a diseased organ encountered. Its fresh weight is measured with an accuracy of 50 or sometimes 20 mgm. The figures are given in Table 2.

The figures compare very closely with those obtained by Bross (2), Castaldi (3), Uemura (4), although their figures are based upon smaller numbers (Table 3). The huge material of Berblinger (5) (1,288 cases) yields somewhat lower results for the epiphysis in both white male and white female. The above investigators have found no particular variation referable to age at any time from the first year onward. I have found no definite correlation with body weight, or with stature. The epiphysis in negroes is significantly smaller than in whites of both sexes, but in the large series of cases there is no significant difference between the sexes. One might well say, with Pastori (6): "Pourtant, je ne saurais avancer aucune hypothèse sur leur fonction."

TABLE 2

Relation of Epiphysis Weight to Body Weight and Stature

SEX AND RACE	NUMBER	MEAN *mgms.*	STANDARD DEVIATION *mgms.*	COEFFICIENT OF VARIATION *per cent*	CORRELATION COEFFICIENT Body Weight	Stature
White male	461	172.40 ± 2.73	86.91 ± 1.93	50.41 ± 1.38	+.173 ± .031	+.115 ± .031
Negro male	263	151.05 ± 3.35	80.61 ± 2.37	53.37 ± 1.95	—.005 ± .043	+.048 ± .041
White female	203	182.92 ± 3.96	83.66 ± 2.80	45.74 ± 1.82	+.189 ± .046	+.043 ± .047
Negro female	179	157.12 ± 4.73	93.89 ± 3.35	59.76 ± 2.79	—.011 ± .051	+.077 ± .050

TABLE 3

Weight of Epiphysis According to Various Investigators

AUTHOR	NUMBER	MALE *mg.*	BOTH SEXES *mg.*	FEMALE *mg.*	MATERIAL
Uemura	71	160	...	151	.....
Bross	92	183	...	151	.....
Castaldi	..	...	156	...	.....
Berblinger	1288	154	...	159	.....
Freeman	663	172	...	183	Whites
	444	151	...	157	Negroes

HYPOPHYSIS

The hypophysis has been subjected to very extensive investigation, and is, perhaps, better known in its quantitative aspects than any other gland. It is easily removed, has a definite capsule and it is a small, solid organ, permitting minute examination.

Rasmussen (7) has performed a signal service by applying the paper-weighing method to estimating the various fractions of the gland, and also, recently, by counting the various types of cells in the anterior lobe. Berblinger (8) on the other hand records grosser studies upon 2,442 cases (excluding pregnant women). Miyazaki (9), in a study of 107 Japanese, gives figures that are of interest from the racial standpoint in connection with my own data on Negroes. Other figures are given by Simmonds (10) upon 800 cases, by Petersilie (11) on 185 cases, and by Roessle (12) on 130 soldiers.

Table 4 gives my own data, and in Table 5 is a comparison of these with those of other authors.

Comparison of the figures in Table 5 shows reasonably close concordance with the exception of Rasmussen's. His glands were very carefully prepared by dissecting off the capsule as nearly as possible, and it is likely that there was some desiccation during the time-consuming procedure. Our own figures are possibly a little high because the gland was not subjected to close trimming. Differences between the sexes and the races are outside the limits of error and must be of significance.

TABLE 4

Relation of Hypophysis Weight to Body Weight and Stature

SEX AND RACE	NUMBER	MEAN *mgms.*	STANDARD DEVIATION *mgms.*	COEFFICIENT OF VARIATION *per cent*	CORRELATION COEFFICIENT Body weight	Stature
White male	474	692.41± 4.72	152.32±3.34	22.00± .50	+.217±.030	+.163±.030
Negro male	269	729.55± 6.31	153.49±4.46	21.04± .64	+.208±.040	+.174±.040
White female	204	762.75± 7.43	157.29±5.25	20.62± .72	+.311±.043	+.200±.045
Negro female	181	814.64±10.01	199.64±7.08	24.51± .92	+.302±.046	+.231±.047

TABLE 5

Weight of the Hypophysis According to Different Investigators

AUTHOR	REFERENCE	MALE *mg.*	MATERIAL AND NUMBER	FEMALE *mg.*	MATERIAL AND NUMBER
Rasmussen	(7)	526.1	111 sudden deaths	620 731 625	43 non-pregnant adults 20 pregnant females 27 post-climacteric
Berblinger	(8)	643*		718*	2442 cases
Miyazaki	(9)	588	Japanese	655	Japanese—107 cases
Simmonds	(10)	688*	800—all ages	771*	
Petersilie	(11)	620	185 unselected	...	
Rössle	(12)	627	130 soldiers	...	
Erdheim and Stumme	(13)	616*	96 adults	684 745 847 1060	Nulliparous women (14) Non-pregnant women (38) Primiparae at term (27) Multiparae at term (18)
Freeman		695 736	485 white males 278 negro males	763 829	207 white females 188 negro females
Lucien	(15)	...	Both sexes together	...	(*Importante série*) 655 mg.

* Approximate.

The enlargement of the hypophysis during pregnancy is notable, according to the figures of Erdheim and Stumme (13) but may be considered temporary in view of Rasmussen's careful studies. Erdheim and Stumme's figures also show that the hypophysis of aged parous women is distinctly larger than that of the nulliparous. There are few data, however, for the nulliparous in the higher age groups.

There is no very great alteration in the weight of the hypophysis referable to age itself. A little atrophy may take place during age involution, but the whole change in the average weight, based upon a survey of the figures available, is probably less than 50 mgm. from youth to age.

While Rössle states that the weight of the hypophysis is, in part, dependent upon the body weight, no data are elsewhere available. The correlation coefficient of about 0.2 between body weight and hypophysis weight is small though significant. The known relationship between the hypophysis and skeletal growth has suggested that the size of the hypophysis might be correlated with stature. Rasmussen (7a) finds a positive correlation of gland weight with stature, $r = +0.279 \pm 0.060$ and when considering the anterior lobe alone, $r = +0.307 \pm 0.059$. Our figures show a small positive correlation, and a similar trend is shown by Roessle-Petersilie's table. Petersilie in white males, and Miyazaki in Japanese have found positive correlation with height, but not with weight. The latter states that the hypophysis is larger in castrated individuals.

The relatively large hypophysis in Negroes, and the small gland in Japanese raises an interesting problem in racial constitution, and this problem will recur in considering other endocrine organs.

The partition of parenchymatous elements in the anterior lobe of the hypophysis has recently been subjected to searching scrutiny by Rasmussen (16). While he has found certain differences that correlate fairly well with what is known concerning the function of the hypophysis, these differences are rather less than would be expected by the constitutional pathologist or endocrinologist. Following his detailed biometrical study upon the various portions of the gland by the paper-weighing method he came to the following conclusions: There is moderate decrease of the anterior lobe after 50 years, with a corresponding increase in the posterior lobe and pars intermedia, but without any increase in colloid. The female hypophysis is larger than that of the male, 13 per cent in young people, 25 per cent in aged individuals. All of this is due to the anterior lobe, the pars nervosa being smaller in the female. In pregnancy, 85 per cent of the whole gland is made up of the anterior lobe, and this seems to increase during the later stages of pregnancy. There is no indication of increased activity of the pars intermedia during pregnancy.

Rasmussen has performed cell counts on the anterior lobe of the hypophysis in males, and recently in females, both pregnant and non-

pregnant. In view of his very accurate method, his figures are more acceptable than those of McCartney (17), which are derived from our own material (Table 6). The estimation of the cellular partition in our cases was done upon a single horizontal section stained by hematoxylin-

TABLE 6

Partition of Cells in Anterior Lobe of Hypophysis

MATERIAL	NUMBER	ACIDOPHILES *per cent*	BASOPHILES *per cent*	CHROMOPHOBES *per cent*	AUTHOR
Males	100 cases	36.8±0.52	10.9±0.25	52.2±0.54	Rasmussen
Non-pregnant females	94 cases	43.4±0.56	7.0±0.20	49.6±0.47	Rasmussen
Pregnant females	25 cases	43.4±1.34	6.3±0.51	50.1±1.26	Rasmussen
Schizoid males		43	17	40	McCartney
Other psychotic males		52	28	20	McCartney
Schizoid females		52	21	27	McCartney
Non-schizoid females		57	20	23	McCartney

eosin, and was not made upon cell-counts, but rather upon a survey of the field under low power. This procedure was terminated when Rasmussen's studies became available, particularly when such widely diverse totals were obtained. It is interesting, nevertheless, from the personality standpoint, to note the difference in the glands of schizophrenic, as compared with the non-schizophrenic (but psychotic) males in St. Elizabeth's Hospital. This feature may be worthy of further investigation.

In males, Rasmussen (7b) finds no correlation of type of cell with body length; men over 50 have 4 per cent more chromophobes and less acidophiles, but the basophiles are unchanged. In females over 50 years of age there are 4 per cent more chromophobes, 2 per cent more basophiles, and 6 per cent less acidophiles. Again there is no correlation of any type of cell with stature. Pregnancy is associated with general hypertrophy, but not limited to any particular type of cell; moreover, no "pregnancy cell" is found. Women have a distinctly higher percentage of eosinophiles, while men are stronger in basophiles and chromophobes.

Kraus and Traube (18) investigated the hypophysis from the standpoint of cellular constituents in 232 cases. They found the basophilic elements increased in sthenics, hypertensives, obese and in nephrosclerotics, while they were diminished in cases of tuberculosis, diabetes, amyloidosis, suprarenal deficiency, and in asthenic individuals. Increased basophilia was found in cases presenting large

suprarenals. The relationship between the basophilic cells of the hypophysis and a syndrome characterized by obesity, hypertension, and suprarenal enlargement, has recently been pointed out by Cushing (19) in a superb monograph.

A few instances of excessive basophilia, not necessarily with adenomatous arrangement, have been found in our series, but only one case corresponded well with Cushing's syndrome. Many small chromophobe adenomata were encountered when the sections were examined under the microscope.

THYROID

Increased prevalence of simple enlargement of the thyroid gland in certain districts and countries has long been known, and "goiter belts" have been mapped out with considerable precision. That the normal thyroid gland varies geographically in the same way has also been known, although the most pointed proof was supplied by Wegelin (20) working first in Kiel and later in Bern, and by Arndt (21) in Russia. On the whole, the thyroid gland is easily dissected out, and needs but slight trimming to obtain accurate weights. The complicated part of the problem is furnished by the selection of the material, since pathologic alterations are moderately frequent. In this study a middle course has been taken, lying between the inclusion of all thyroids, and the exclusion of all glands bearing visible nodules or cysts. Where the nodules seemed to result from fibrosis, without hyperplasia, or when only a few minute cysts or nodules were present, the gland was considered sufficiently normal to be included in the study. Actually, indeed, relatively few thyroids were thrown out on account of pathologic lesions, although more thyroids were excluded than any other organ studied except the prostate. The comparative absence of thyroid enlargement may be attributed to the coastal location of the City of Washington, to the rather advanced age of the patients, and to their long stay in the hospital. It is possible, also, that thyroid deficiency may be related in some way to the presence of certain of the psychoses. Table 7 gives our findings in regard to sex and race, weight of body and stature, while Table 8 compares these results with those of other investigators.

The thyroid is somewhat smaller in women than in men, although during the adolescent years, Wegelin indicates, the gland may be twice as large in girls as in boys. His figures in 166 cases between 10 and 20 years are: Male, 16.8 gm., female, 30.1 gm. All the figures given in this paper concern adults alone. After reaching adult proportions, the thyroid remains remarkably constant in average weight,

TABLE 7

Relation of Thyroid Gland Weight to Body Weight and Stature

SEX AND RACE	NUMBER	MEAN *gms.*	STANDARD DEVIATION *gms.*	COEFFICIENT OF VARIATION *per cent*	CORRELATION COEFFICIENT	
					Body weight	Stature
White male	459	21.67± .27	8.69± .19	40.10±1.03	+.256±.030	+.136±.031
Negro male	262	22.42± .36	8.73± .26	38.94±1.31	+.315±.038	+.106±.041
White female	185	16.72± .38	7.64± .27	45.69±1.91	+.227±.047	+.139±.049
Negro female	161	20.67± .44	8.35± .31	40.40±1.75	+.343±.047	+.068±.053

TABLE 8

Weight of Adult Thyroid Gland in Different Parts of the World

AUTHOR	LOCALITY	NUMBER	MALE *gm.*	BOTH SEXES *gm.*	FEMALE *gm.*	MATERIAL
Rössle	Germany ...	482	34	...	...	Soldiers
Rössle	Jena & Basel	811	31.1	...	30.2	.....
Wehefritz	Jena	529	...	...	28.0	.....
Wegelin	Kiel	73	21.7 *	...	23.0 *	.....
Wegelin	Bern	56	...	41.6	...	.....
Arndt	Moscow	830	...	18 *	...	.....
	Minsk			39 *	...	.....
	Irkutsk			43 *	...	.....
Castaldi	Florence ...	121	19.7	...	18.4	.....
Villela and P. deAzevedo ..	Rio de Janeiro	...	20.99	...	15.53	.....
Horisawa	Japan	...	17.5	...	15.3	Japanese
Jaffé	Chicago		27.4	...	28.1	Whites
			27.4	...	24.6	Negroes
Freeman	Washington.	644	21.7	...	16.7	Whites
		423	22.4	...	20.7	Negroes

* Approximate. The figures are given in various age groups.

according to Rössle's (22) large statistics. Castaldi (23), however, indicates rather definite atrophy of the gland in aged individuals, and Jaffé (24) shows it for females, but less so for males.

Racial differences are probably less important than was formerly considered. Goiter is apparently non-existent in Japan, and Rössle emphasizes the smallness of the glands, utilizing Horisawa's (25) statistics. Data from South America, however, are more or less in line with these figures, and our own are not far off. Indeed, the recent work of Thomas (25a) in Ghent shows similar results. Little difference is found between White and Negro races of the same locality. As in Germany, so also in the United States, the thyroids from up country are larger than are those of the sea-coast. Our aberrant figures for white females are not easily explained. The low average is not due to the inclusion of a large number of aged atrophic individuals, since the same discrepancy appears before the age of 50 years.

On the other hand, even greater differences between male and female were found by Villela and P. de Azevedo (26) in Rio de Janeiro.

Jaffé looks at the thyroid through a pathologist's glasses. After the age of 60, he says, two-thirds of the thyroids from white females contain nodules, and 69.3 per cent of goiters are nodose. Diffuse colloid goiters appear early, and the nodose enlargements increase with age. Hellwig found goiter in 17.5 per cent of all necropsies at Jena (4,327 cases), while the nodose form occurred in 11 per cent. In Irkutsk, nodose enlargements occurred in 45 per cent of all adults (Arndt). Rössle finds greater correlation with distance from the coast than anything else, and this would accord well with Marine's (27) ideas in regard to the relationship of available iodine. In our series, probably less than 5 per cent of the glands were discarded because of significant lesions.

I have encountered no statistics dealing with the size of the human thyroid in relation to that of the body. Marine gives the figure 0.30-0.35 gm. per kilo body weight, and other similar simple expressions are found in classical tables like Vierordt's. The coefficient of correlation between thyroid weight and body weight is considerable, in comparison with that of other endocrine organs. As far as stature goes, there is barely enough to consider, and probably all this difference may be accounted for by the greater body weight of the taller individual. Finally, the coefficient of variation in the weight of the thyroid shows that this gland is rather more variable than most of the endocrine organs, but distinctly less so than the thymus and the ovaries.

Rössle found a standard deviation between 9 and 10 grams for the males, and slightly more for the females in his long series, and he stipulates that nodular thyroids were excluded.

PARATHYROIDS

Several problems are presented to the biometrician in the study of the parathyroid glands. The little bodies are variable in number and position, and are so small that all of them are not easily discovered in the course of a routine necropsy. They may be confused with small adjacent lymph nodes, and also with bits of aberrant thyroid tissue. Occasionally they lie embedded in the substance of the thyroid gland. Moreover, they are soft and easily torn, and it is difficult to trim away the fat completely without sacrificing some of the parenchyma. Moreover, in the process of trimming and weighing, a certain amount of fluid evaporates, thus leaving the glands lighter than they should be. There is a variable amount of fat within the gland, sometimes amounting to 50 per cent or more, and cysts sometimes occur. A research like that of Hammar upon the thymus, or of Rasmussen upon the hypophysis,

is needed for the better delineation of the anatomical characteristics of the gland, using cell counts and paper-weighing methods. We have submitted several hundred sets of glands to section and have estimated the amount of active glandular tissue present, but have not reached the stage of correlating our figures with clinical conditions.

Danisch (28) has done the most accurate work up to the present. He noted the hyperplasia of the chief cells in osteoporosis, although osteoporosis was not constant, and also the high proportion of oxyphile cells in arteriosclerosis and calcifying conditions in the body. In a case of diabetes he found adenomatous overgrowth. Cysts may occur in myxedema.

Kurokawa (29) concludes from a study of 240 sets of glands that in tuberculosis and syphilis fibrosis is the rule, that oxyphile cells are increased in cancer cases and in pregnancy and that follicular formations occur in cases of sarcoma of bones.

Impressions are apt to be misleading in both directions, but in additional studies on this same material I have not been struck by the specificity of alterations. Certainly in three cases of Paget's disease, the parathyroids were indistinguishable from normal glands, and in certain cases unusually large sets of glands, weighing as much as [illegible] mg., have been found without definite alterations in the osseous system. Danisch had only 42 cases in adults, and the weights in these cases are not out of line with our own, as given in Table 9. Aging apparently produces only slight increase in the weight of the parathyroid glands.

Sexual differences in the parathyroids are absent, but there may be some slight racial differences. The positive correlation of the weight of the glands with body weight is fairly definite though small, but the rather notable positive correlation of weight with body length in white males is not borne out in the other groups. In view of the multitude of technical difficulties in getting an accurate weight of the parathyroid glands, such small differences are probably insignificant, and further study by projection of serial sections is necessary to elucidate the function of the little bodies in terms of structure.

THYMUS

The thymus gland carries more uncertainty in regard to its function than any other endocrine, with the exception, possibly of the pineal; and it is more variable in size and in parenchymatous constituents than is any other. This applies particularly to the adult thymus, since most

TABLE 9

Relation of the Parathyroid Glands to Body Weight and Stature

SEX AND RACE	NUMBER	MEAN *mgms.*	STANDARD DEVIATION *mgms.*	COEFFICIENT OF VARIATION *per cent*	CORRELATION COEFFICIENT Body weight	CORRELATION COEFFICIENT Stature
White male	470	151.06±2.29	73.49±1.62	48.65±1.30	+.221±.030	+.277±.029
Negro male	274	166.24±3.51	86.16±2.48	51.83±1.85	+.248±.039	+.115±.040
White female	203	146.22±3.17	67.06±2.24	45.87±1.83	+.116±.047	+.044±.047
Negro female	183	168.44±4.15	83.21±2.93	49.40±2.12	+.197±.048	−.065±.050

of the cellular elements have undergone resorption and replacement by fat. The occasional complete preservation of the parenchyma renders the problem yet more difficult.

Hammar (30) in a monumental work reporting researches of thirty years, came to a number of important conclusions, the chief one of which was that if the terminal illness from which the patient suffered were more than a day or two in duration, profound changes were to be expected in the gland. Furthermore, he denied the commonly held opinion that enlargement of the thymus could explain the sudden unexpected deaths of so-called status thymicus, since control glands of individuals suffering accidental deaths were of equal size. These conclusions have also been substantiated by Boyd (31) upon the large Minneapolis material.

In the adult individual, even in the senile period, there may be more or less persistence of the lymphoid structures in the thymus gland, although Hassal corpuscles and division into cortex and medulla are seldom observed. The fat with which the gland is invested makes its delineation difficult. In our own studies the fat overlying the pericardium has been dissected free as far up as the innominate veins, and trimmed to the semblance of thymus before being weighed. In a large number of cases a section has been made through the body of the gland in order to determine roughly the percentage of active parenchymatous tissue present. Here again, however, the details of our own studies are scarcely worth quoting, since the painstaking work of Hammar, and its statistical elaboration by Boyd under Scammon's direction, has been based upon the paper-weighing method, and upon the estimation, in serial sections, of Hassal's corpuscles. In the works quoted, attention has been focussed upon the earlier age periods, and upon the charts, 50 years finds equal expression with five prenatal months. The changes during those few months, however, are several times as great as those occurring during the whole of senescence.

Preliminary studies upon the weight of the thymus showed that there was little difference between the averages for adults under fifty years, and those over fifty, although the older individuals, on the whole, carried larger glands. The organs were not selected, nor in this study was the percentage of lymphoid tissue recorded. The small difference is probably explained by the greater body weight in older subjects. The details are presented in Table 10.

The figures range somewhat higher than do those of Boyd upon strictly normal cases of sudden death. Relatively few data are available

TABLE 10

Relation of Adult Thymus to Body Weight and Stature

SEX AND RACE	NUMBER	MEAN *gms.*	STANDARD DEVIATION *gms.*	COEFFICIENT OF VARIATION *per cent*	CORRELATION COEFFICIENT Body weight	Stature
White male	469	17.81± .44	14.22± .31	79.84±2.65	+.405±.026	+.011±.031
Negro male	274	12.21± .40	9.81± .28	80.34±3.50	+.515±.031	+.012±.041
White female	207	15.39± .60	12.77± .42	82.98±4.24	+.519±.034	+.143±.046
Negro female	177	12.25± .46	9.04± .32	73.80±3.82	+.506±.038	+.028±.051

upon adults, the best series being that of Lowenthal (32) upon soldiers. All of the statistics show the trend by age groups, which makes averages somewhat difficult to calculate. In 160 adult cases recorded in Boyd's Table 2, the average median weight was 17.0 gm.

The tables appended in this study (Tables 10, 11, 12) indicate several features worthy of mention. There are no significant differences due to sex; this has also been determined by other investigators.

TABLE 11

Weight of Adult Thymus Gland According to Different Investigators

AUTHOR	NUMBER	WEIGHT *gm.*	
Friedleben	17	9.9	
Hammar	59	17.7	
Lowenthal (35)	90	21.4	(Soldiers)
Rössle (36)	86	14.2	
Rössle (36)	88	12.8	(Sudden deaths)

TABLE 12

Weight of Thymus Parenchyma (Estimated) According to Hammar (30)

AGE	WEIGHT OF PARENCHYMA *gm.*
21-25	10.05
26-30	5.89
31-35	4.86
36-45	3.79
46-55 .	1.23
56 plus	1.0

The higher weight in whites is significantly beyond the limits of error in sampling. The effect of age is much more marked in the involution of the parenchyma (Table 12) than it is in the change of weight of the whole structure. Undoubtedly this is accompanied by the increase in

interstitial tissue and fat. The thymus is more highly correlated with body weight than any other endocrine organ, reflecting once again the nutritional status of the body, however, rather than any innate function of the gland itself. On the other hand, there is no definite correlation with stature. The glands in this study have not been separated according to the duration of the last illness, a procedure adopted by Boyd and also originally by Friedleben (33). The figures set down are closely parallel, however, with those observed by other individuals who have selected patients succumbing rapidly (Table 11). In children, undoubtedly, the selection of cases would be a more important procedure, since the wasting of the parenchymatous portion of the thymus is extremely rapid. In adults, however, the large proportion of fat makes the thymus behave more nearly like a fat depot.

Certain other details of Table 10 throw light upon the behavior of the thymus gland. The coefficient of variation is higher for the thymus than for any other of the structures under consideration. Persistence of more than 20 per cent of the thymic parenchyma has been noted in a certain proportion of cases, most frequently among those suffering from convulsions (18 per cent). Closer study of this observation may yield some interesting points on constitutional variations, but I would not suggest that persistent thymus and convulsions have any cause and effect relationship. It is probable that this indicates only that death has occurred rather suddenly; on the other hand, it may be that a positive water balance is associated with delayed involution of the lymphoid structures, as well as with convulsive seizures.

SUPRARENALS

The suprarenal glands are of exceptional interest to the endocrinologist, because of the manifestations of insufficiency and overactivity, because of their necessity for continued existence, and because of the recent isolation of the active principle cortin. The psychiatrist is keenly interested in the stimulation of the intellectual faculties and the postponement of mental fatigue following administration of cortin to sufferers from Addison's disease. Thus far, however, the results in mental diseases have been disappointing.

The pathologist is confronted with certain problems, however, that render rather difficult elucidation of the rôle of the suprarenals in human constitution. The suprarenals are often somewhat difficult to

TABLE 13

Relation of Right and Left Suprarenal Glands to Body Weight and Stature

SEX AND RACE	NUMBER	MEAN *gms.*	STANDARD DEVIATION *gms.*	COEFFICIENT OF VARIATION *per cent*	CORRELATION Body weight	COEFFICIENT Stature
			Right			
White male	472	7.41± .07	2.12± .05	28.61± .68	+.358±.027	+.253±.029
Negro male	273	6.84± .09	2.08± .06	30.41± .96	+.222±.040	+.238±.039
White female	207	6.64± .09	1.94± .06	29.22±1.05	+.427±.039	+.348±.041
Negro female	185	6.09± .08	1.53± .05	25.12± .93	+.128±.049	+.230±.047
			Left			
White male	471	7.79± .07	2.33± .05	29.91± .71	+.319±.028	+.299±.028
Negro male	271	7.49± .10	2.44± .07	32.58±1.04	+.190±.040	+.172±.040
White female	207	6.79± .10	2.12± .07	31.22±1.13	+.409±.039	+.339±.041
Negro female	184	6.65± .09	1.87± .07	28.12±1.06	+.072±.050	+.218±.047

dissect out cleanly. Their surface is folded so that a variable amount of fat is apt to be included with the gland, if, indeed, some of the gland has not actually been snipped off during the process of trimming. Deposits of lipoid material are common in arteriosclerosis. Atrophy of the suprarenals in inanition may be very considerable, and yet, with the lighting up of almost any infection there may be great swelling of the cortex and liquefaction of the inner cortical zones.

Materna (37), for instance, found that the pairs of glands without cortical softening weighed 12.13 gm., while those that were softened weighed 14.48. In fact, in 25 accidental deaths, the same author found the average weight of both suprarenal glands to be 9.34 gm. Jaffé (38) is also of the opinion that individuals dying by accident have glands that weigh below 10 grams, while the general average is between 11 and 12. Rössle (39) gives almost identical figures for cases of sudden death and for the general average (14.1 and 13.9 gm. respectively). Parhon and Zugravu (40) found average weights of about 16 grams in their psychotic material, very closely agreeing with my own.

TABLE 14

Weight of Both Suprarenal Glands (Adults) According to Different Authors

AUTHOR	NUMBER	MALE *gm.*	FEMALE *gm.*	MATERIAL
Rössle and Roulet.....	374	13.9	...	.....
	485	...	12.8	.....
Rössle	425	14.1	...	Soldiers
Jaffé and Sternberg....	...	13.48	...	Soldiers
Leupold (43)	107	11.28	...	.....
Materna	150	12.13		Both sexes
	21	8.75	9.85	Accidental deaths
Schilf	409	12.5	...	Soldiers
Parhon and Zugravu...	224	16.1	13.0	Insane

The figures given in Table 13 are from my own studies, the glands being separated right from left. The left gland is a little heavier. Correlation of the weight of the glands with body weight is rather higher than that which occurs in the other glands (thymus excepted) but of the same general order. However, correlation with stature is quite surprisingly high, and fairly consistent in the various groups. The reason for this correlation is not apparent.

It is interesting that Schilf (41) found some correlation with body height, but the highest correlation was with the weight of the heart, at least as far as the age of 16. The stability of the suprarenals is also indicated by graphs and tables in Rössle, showing that during maturity there is a relatively insignificant deviation attributable to age alone. Indeed, the curves for suprarenals and for brain might almost be superimposed.

I have seen no figures on the involution of the maternal suprarenals after childbirth. Geographical and other data of biometrical significance are largely indefinite, although Goldzieher (42) and Materna have covered the field as well as any.

TESTES

There are surprisingly few papers dealing with the weight of such easily accessible organs as the testes. This is particularly significant with regard to psychiatry, since the sex glands have been blamed for so many mental aberrations, and since sexual perturbations are such a common feature in the psychoses.

Moreover, there are few pertinent data upon racial variations, although Oiye (44) in 482 Japanese men, found the weight of both testes plus epididymides to average 12.08 gms., about half the weight of the European glands. The figure of 40 to 60 grams (including epididymis) given by Jaffé and Berberich (45) is believed to be too high, even by Rössle, and the statistics of Leupold (46) in 86 adults give 28.0 grams for both organs. The largest series is reported by Rössle (47), divided, as usual, by age groups, although there is relatively slight decrease in the size of the glands with increasing age. His data from soldiers and other typical cases of sudden death give somewhat higher figures than his unselected cases. For all adults, the average found by him in 623 cases is not far from 35.0 grams. One hundred and ninety selected cases reach 39.1 grams, these mostly being from soldiers killed in action, i.e., young adults in full vigor. There is some uncertainty in Rössle's statistics as to the presence of the epididymis in his material. He particularly emphasizes the fact that Leupold's glands were trimmed, although I cannot tell whether his own were. If his own figures included the epididymis, they are not strictly comparable with my own which were trimmed. Indeed, the figures of Leupold are much nearer to those given in this study. Fischer (47a) gives the weight of the epididymis as 3 grams. Allowing 6 extra grams for the sacrificed epididymides, this reunites Leupold's and my figures with those of Rössle at 34-35 grams for both glands.

My own figures are given in Table 15.

TABLE 15

Relation of Testes Weight to Body Weight and Stature

RACE	NUMBER	MEAN *gms.*	STANDARD DEVIATION *gms.*	COEFFICIENT OF VARIATION *per cent*	CORRELATION COEFFICIENT Body weight	Stature
White (right)	472	15.20± .17	5.48± .12	36.05± .89	+.367±.027	+.130±.031
White (left)	473	14.45± .17	5.34± .12	36.96± .91	+.306±.028	+.096±.031
Negro (right)	269	12.82± .19	4.56± .13	35.57±1.16	+.408±.035	+.222±.039
Negro (left)	270	12.72± .20	4.79± .14	37.66±1.24	+.345±.037	+.124±.040

TABLE 16

Relation of Prostate Weight to Body Weight and Stature

RACE	NUMBER	MEAN *gms.*	STANDARD DEVIATION *gms.*	COEFFICIENT OF VARIATION *per cent*	CORRELATION COEFFICIENT Body weight	Stature
White	396	25.13± .34	10.16± .24	40.43±1.12	+.296±.031	—.024±.034
Negro	235	22.62± .40	9.05± .28	40.01±1.43	+.299±.041	+.126±.043

There is a difference of about 0.75 grams in the average weight of the testis between those in my series under fifty years and those over that age, indicating a slight loss during senescence, but this is scarcely significant. The rather marked difference in the size of the testes in the white and in the negro race was unexpected on account of the generally larger size of the external genitalia in the colored race. There is a moderate correlation with body weight, and a slight one with stature. The variability of the glands is about equal to that of the hypophysis. Other authors, mentioned by Rössle and Roulet, have emphasized the relation between the size of the testes and the nutritional state of the body, and Schilf (41) and Leupold (43) have found a positive correlation with the weight of the suprarenals. My own studies (48) have shown larger testes in the cycloid group than in the noncycloid.

PROSTATE

The prostate gland is quite variable in size, and is somewhat difficult to dissect out in its entirety, without leaving some adhering bits of bladder, urethra or seminal vesicle. Moreover, it is as frequently the seat of minor abnormalities as is the thyroid gland.

The normal gland, according to Simmonds (49), who studied 500 cases, reaches its maximum development in the sixth decade, when it weighs 18 grams, then falling off about one gram per decade. The average gland continues to increase in weight, however, on account of the presence of simple hypertrophy or of adenomatous nodules. Rössle (50) finds the prostate very constant at 20 grams from the age of 35 up to the age of 65 years, but has no definite figures after that date.

My own figures are given in Table 16. They range somewhat higher than the averages given by other authors, although about 20 per cent of the glands have been excluded on account of abnormalities. This difference is probably due to the inclusion in the statistics of many old men, but the figures are useful in pointing out racial differences. The prostate follows the testis in being significantly larger in white men than in Negroes. There is some correlation with body weight, but none with stature.

OVARY

Among the organs under consideration, the ovary shows the greatest change in weight from early maturity to senility, as shown in the curve plotted by Rössle and Roulet (51). The peak is reached at 11.3 gm.

TABLE 17

Relation of Weight of Ovaries to Body Weight and Stature

RACE	NUMBER	MEAN *gms.*	STANDARD DEVIATION *gms.*	COEFFICIENT OF VARIATION *per cent*	CORRELATION COEFFICIENT	
					Body weight	Stature
White (right)	176	2.10± .08	1.51± .05	71.90±3.69	+.154±.050	+.144±.050
White (left)	167	1.94± .07	1.33± .05	68.56±3.52	+.100±.052	+.214±.050
Negro (right)	135	2.51± .10	1.70± .07	67.73±3.85	+.049±.058	+.108±.057
Negro (left)	128	2.29± .09	1.48± .06	64.63±3.64	−.119±.059	+.074±.059

(for the two organs) at the age of 25, sinking to 4.0 gm. at 65 years. In our own handling of the material, there is a significant statistical difference between the weight of the ovary in those under 50 years, and in those over that age. Included in our statistics are numerous examples of organs that are at most partially freed from their investing adhesive connective tissue, since pelvic adhesions are found in a high proportion of negro females. Organs with cysts have been excluded (Table 17).

TABLE 18

Weight of Both Ovaries According to Age (Rössle)

AGE	NUMBER	AVERAGE *gm.*	STANDARD DEVIATION *gm.*
11-20.....	65	7.94±0.50	4.06
21-30.....	91	11.30±0.46	4.44
31-40.....	88	10.66±0.52	4.87
41-50.....	85	7.52±0.35	3.23
51-60.....	87	5.03±0.67	6.26
61-70.....	83	4.13±0.57	5.22
71-90.....	54	4.09±0.64	4.69

TABLE 19

Effect of Pregnancy on the Weight of the Ovaries, Thyroid and Suprarenals

	PREGNANT *gm.*	NON-PREGNANT *gm.*
Ovaries	13.60	8.8
Thyroid	40.69	25.68
Suprarenals	13.57	11.57

The high coefficient of variation is notable, most organs being small, but a few reaching large size.

In Rössle's (52) figures the standard deviation is even higher than the mean (Table 18). Wehefritz's figures (53) run slightly lower than Rössle's for the same age groups but their material was much the same. Wehefritz gives (54)

interesting figures for the ovaries, thyroid and suprarenals in pregnant and non-pregnant women (Table 19).

Our own material has so many aged individuals (only 33 white and 38 colored females under fifty years) that the figures are not strictly comparable with those of Rössle and of Wehefritz. The differences due to race, body weight and stature are relatively insignificant. The ovaries in most of our patients might almost be spoken of as anatomic landmarks.

UTERUS

The uterus, like the ovary, is subject to considerable changes in weight during the process of maturity and senescence, although these are less marked than in the case of the ovary. Other factors, particularly the presence of fibroid tumors and polyps, often alter the normal weight of the organ, so that by the exclusion of these, the number of organs available for study of the normal is much reduced. Indeed, more than half of the uteri of the negro females have had to be eliminated because of significant pathologic lesions. In Tables 20 and 21 are the significant data in regard to the weight of the uterus, Table 21 being taken from Rössle and Roulet (55) much of whose material was elaborated a few years earlier by Wehefritz. In both tables no note has been made as to whether the uteri came from nulliparous females or from those having borne children. Pregnant uteri, however, have been excluded by the German investigators, and have not entered into our material at all.

The larger size of the uterus in the colored race seems well established by the figures, although the difference might be reduced if allowance had been made for the somewhat more advanced age of the white females. It is also worthy of note that the negro females show a somewhat higher average body weight than the white females, amounting to slightly more than two kilograms. The relatively high coefficient of correlation between body weight and uterus weight indicates some dependence of the uterus upon the nutritional state of the body, and these two factors, age and body weight, would therefore tend to obliterate the differences due to race alone. On the other hand, it is emphasized that many of the negro females are at least half white, and again that the negro female averages somewhat higher in regard to the number

TABLE 20

Relation of Weight of Uterus to Body Weight and Stature

RACE	NUMBER	MEAN *gms.*	STANDARD DEVIATION *gms.*	COEFFICIENT OF VARIATION *per cent*	CORRELATION Body weight	COEFFICIENT Stature
White	159	38.70± .93	17.47± .66	45.14±2.03	+.425±.044	+.116±.053
Negro	88	46.14±1.30	18.12± .92	39.27±2.28	+.310±.065	+.158±.070

TABLE 21

Weight of the Uterus in Relation to Age (White Females)
From Rössle and Roulet

AGE	NUMBER	MEAN WEIGHT *gm.*	STANDARD DEVIATION *gm.*
21-30.....	68	49.26±2.09	17.01
31-40.....	67	52.35±2.10	17.20
41-50.....	62	58.00±1.66	13.09
51-60.....	84	51.76±1.60	14.74
61-70.....	84	41.40±1.53	14.03
71-90.....	58	37.81±1.62	12.37

of pregnancies. A study of purely racial differences in the uterus, as well as in other organs, is beset with difficulties, and the results are susceptible of different interpretations.

SUMMARY AND CONCLUSIONS

The endocrine system of the body is of great importance in regulating growth, metabolism, somatic activity, and possibly mental activity. It was with a view to determining how much this system had to do with mental activity, in particular with types of behavior, that the present study was mapped out. This paper presents the more fundamental aspects of the endocrine organs, emphasizing the alterations in the weight due to race, sex, body weight, stature, and, to some extent, age. It is emphasized that significantly diseased organs have been excluded, but attention is also called to the difficulties both in the gathering of accurate raw data, and in the final interpretation of the results.

With few exceptions, the gross weight of the organs investigated has thrown little light upon their relative activity. While correlations are fairly high between the body weight and the weight of certain organs, this probably means only that the organs share in the general nutrition of the body, and atrophy when the flesh falls away. Probably the most important conclusion from the whole study is that there is a moderate correlation between stature and the weight, not of the hypophysis, but of the suprarenals. This has been hinted at, but, as far as I am aware, has not been discussed at length. The pronounced

differences between the weights of the testes in white, Japanese and negro races is of considerable interest. In this instance there seems to be some validity to the suggestion that these differences are truly racial. However, the differences in the weight of certain other glands, notably the thyroid, would seem to be conditioned geographically rather than racially.

It is emphasized that the gross weight of any gland is no indication of its biologic activity, and that one cannot tell what an organ can do merely by looking at it. Following the lead of Hammar who spent his life on the thymus, with a few important conclusions drawn, Rasmussen has subjected the pituitary body in a similar way to minute investigation and has drawn some important conclusions. However, even after the cells have been counted and the proportions of the gland measured by the so-called paper-weighing method, the findings still leave unanswered many questions that await solution.

In defense of this method of approach to the study of mental disorders, it may be said that if statistically significant differences are found in the glands of men who behave differently, even though due allowances are made for age, sex, race, weight, and stature, then these differences will assume an importance far beyond the few grams, or milligrams even, that may separate their mean weights.

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The growth of organs has interested pathologists much more than their involution, hence there is much more information on the early months or years of life than there is at the other end. The works most used in this contribution have been (1) the small volume, unique in its way, by Rössle and Roulet: *Mass und Zahl in der Pathologie*, Berlin, 1932, Springer; (2) The massive *Handbuch der inneren Sekretion*, edited by Hirsch, Volume 1 giving the anatomical and pathological details. Monographs by Hammar on the thymus, by Goldzieher on the suprarenals, and the splendidly scientific papers of Rasmussen on the pituitary are noteworthy. Scammon's section in *The Measurement of Man*, Minneapolis, 1930, gives interesting details of prenatal and postnatal development, but devotes much less attention to adult years. The biometrical study of normal organs was begun by W. Müller in Jena and continued actively and fruitfully by Rössle to whom the War brought abundant material. It must not be thought that the endocrine system bulks large in his little book; actually only one-sixth is devoted to the organs studied in this paper. The rest is equally valuable and stimulating. Particular references are given below.

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ANATOMIC LAG

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THE human organism conforms in varying degree to an anthropometric pattern. Tall individuals have long arms, wide shoulders, long heads. The proportion of one dimension to another varies, both within a group and from group to group, but there are limits to the range of variation. The proportion of length of hand to stature, for example, is not constant, but there is a lower and an upper limit to the range. A similar observation applies to the proportion between any two dimensions. Generally speaking, head or body dimensions in the same direction, vertical or horizontal, transverse or antero-posterior, are more closely related, that is, have a higher positive correlation, than do dimensions in different directions. Thus stature is relatively highly correlated (positively) with leg length, arm length, hand length, and foot length; shoulder width is relatively highly correlated (positively) with width of hips, transverse diameter of arm or of leg, thoracic width, width of neck, and so on. When, however, two anatomic dimensions are positively correlated, it will be found that if one is selected as the independent variable, the other will vary with it in smaller proportion, though not necessarily at a decreasing rate. Thus if we select on the basis of head length individuals of a local group, of like age, sex, and race, we find that those with the absolutely widest heads have the relatively widest heads, and those with the absolutely longest heads have the relatively longest heads. That is to say, in a given ethnic group, head width is relatively greatest in the shortest heads, and relatively least in the longest heads. As we proceed, therefore, from the lowest to the highest values of head length, head width lags, that is, becomes relatively less in terms of length. The converse is the case if we select head width as the independent variable. We then find that head length is relatively less in the widest heads, and relatively greater in the narrowest heads. With increase in width of head, length of head lags, and conversely. Such, presumably, is the case

with regard to most paired body dimensions, unless one dimension is a part of the other. The tendency for one dimension to vary with another is, of course, expressed in the usual coefficient of correlation (r); r, however, gives no intimation of lag, much less of its degree. It seemed worth while, therefore, to analyze various pairs of variables from the point of view of anatomic lag. Our procedure was to ascertain the mean value of one (dependent) variable for each unit of the other (independent) variable, as is done in computing the η correlation ratio; and then to compute the average change in the dependent variable at each interval of the independent variable. In one series the rate of change was calculated by the formula, rate = difference divided by ½ the sum of the adjacent values. The amount of change can be expressed as the average amount for one unit increment (or decrement) of the independent variable. To make dimensions comparable an index may be used, computed in the following manner:

When X and Y are two dimensions, $\frac{\text{Range in units of } x \text{ times } 100}{\text{Mean of } x\text{'s of range}}$ is divided into $\frac{\text{Range of corresponding } y\text{'s times } 100}{\text{Mean values of extreme } y\text{'s of numerator}}$. When X is a dimension and Y is the index $\left(\frac{x}{y} \text{ or } \frac{y}{x}\right)$, divide e = range of x into the range of the corresponding y values. By reducing numerical range of dimension to percentage of mean or of median, the various indices of lag are comparable irrespective of the size of the dimensions. Since an index is a percentage, its variation weights the relative variations in the respective dimensions. The above method assumes a normal distribution and hence a larger number of cases than is procurable in the usual series of anthropometric data. When the series consists of individuals it is, therefore, desirable to take an average for individuals at the lower and upper end of the scale, respectively, partially to offset the variation in value due to chance. The standard deviation would be a good statistical measure of the range which should be included in such samples at the extremes of the series. Unfortunately, this would diminish the range. When a sufficient number of series are checked against one another, the errors due to chance would tend to cancel out; but such an average for series would hide the differences between series. When a series consists of individuals, we have, therefore, employed the difference between the lowest and highest values of independent variable, and also, as a check upon their reliability, have used the average of approximately the 5 per cent at the respective extremes of the range. We shall call this latter

the weighted index. This index may diminish the influence of the most extreme individuals upon the index of lag; indeed an analysis of some series indicates that the amount of lag is significantly different in parts of the range.

LAG IN SKULL DIMENSIONS

The first interrelationship of dimensions tested by this method was that between skull length and skull breadth. We utilized three series of European crania for which mean glabello-occipital length had been computed for each interval of cranial index.[1] These series have the distribution of indices given in Table 1.

TABLE 1

Analysis of Series Used Below

GROUP	PER CENT DOLICHO-CEPHALIC	PER CENT MESO-CEPHALIC	PER CENT BRACHY-CEPHALIC	S. D. OF C. I.
Tenerife	26	67	7	2.3
Greifenberg	7	24	69	4.8
Merovingian	34	46	20	4.5

The series of Table 2 shows, taken in its entirety, a lag in head length with increase in cranial index, that is, with increase in relative head width. If we use the values for the interval of cranial index 72-80, inclusive, in which there are 9 or more skulls in each class interval, the average lag for 1 increment unit of cranial index is —0.88. This series has a comparatively small range of cranial index, and, as indicated in Table 1, a small standard deviation of cranial index.

Analysis of each series into thirds of range (Table 5) fails to show any consistent difference in rate of lag at different points of the range, unless there be a tendency for rate of lag in skull length to decrease with higher cephalic index, that is, with short skull. In two series the rate of lag is significantly low in the uppermost third of cephalic index—in fact, head length is slightly accelerated.

[1] Ruth Sawtell Wallis, "Cranial Relationships and Correlations," *Human Biology*, Vol. 6, pp. 308-323, 1934.

TABLE 2

Relation Between Skull Length and Cranial Index in Tenerife Male Skulls (Data of E. A. Hooton, Arranged by R. S. Wallis)

CRANIAL INDEX	NO.	MEAN LENGTH	CHANGE AT INTERVAL	RATE OF CHANGE	DIFFERENCE (½ SUM OF VALUES)
70	1	187	...	.....	
71	2	185	—2	—1.07	
72	9	190	+5	+2.66	
73	10	187	—3	—1.59	
74	25	188	+1	+0.50	
75	34	186	—2	—1.70	
76	46	187	+1	+0.50	
77	35	185	—2	—1.08	
78	38	184	—1	—0.54	
79	21	187	+3	+1.62	
80	14	183	—4	—2.16	
81	5	181	—2	—1.10	
82	3	180	—1	—0.59	
83	1	185	+5	+2.74	
Total	245	185.3	—2	—1.81	
Average for each unit of C. I., and Index of lag			—0.15	—0.14	
Weighted index of lag			—0.21	(for cephalic index 70, 71-82, 83).	

The exact differences appear only when the amount of change is expressed as a percentage of the values of the numbers which constitute the interval, but the above results approximate these differences.

When the above skulls are arranged on the basis of the same range of cranial index the differences in lag between the three series are as shown in Table 6.

Thus the rank order of lag in the three series is the same for the total of the respective series as for the range of cephalic index common to the three series. This is also the rank order of standard deviation of cranial index in the three series (see Table 1). The coefficient of correlation of skull length-skull width has the inverse rank order, being much higher in the Tenerife than in either of the other two series.

TABLE 3

Relation Between Cranial Index and Skull Length in Merovingian Males (Data of R. S. Wallis)

CRANIAL INDEX	NO.	SKULL LENGTH (MEAN)	CHANGE IN VALUE AT INTERVAL
66	1	202	...
67	..	...	...
68	2	195	...
69	1	197	+2
70	3	193	—4
71	7	193	0
72	9	194	+1
73	8	188	—6
74	18	190	+2
75	9	189	—1
76	14	187	—2
77	9	186	—1
78	12	184	—2
79	7	182	—2
80	6	183	+1
81	3	180	—3
82	9	182	+2
83	4	183	+1
84	3	179	—4
85-89	..	...	...
90	1	172	...
91	1	173	+1
92	..	...	...
93	1	163	...
Total	130	185.6	—16

Average lag for 1 unit of cranial index... —1.44
Weighted index ..... —0.64

TABLE 4

Relation Between Cephalic Index and Skull Length in Greifenberg Male Skulls (Data from H. Shapiro, Tabulated by R. S. Wallis)

CEPHALIC INDEX	NO.	MEAN LENGTH	CHANGE IN VALUE AT INTERVAL	
71	2	200	...	
72	0	...	...	
73	3	192	...	
74	5	187	—5	
75	8	186	—1	
76	7	188	+2	
77	11	185	—3	
78	13	182	—3	
79	11	180	—2	
80	32	181	+1	
81	21	182	+1	
82	29	178	—4	
83	25	178	0	
84	37	176	—2	
85	19	174	—2	
86	22	173	—1	
87	12	173	0	
88	15	172	—1	
89	8	170	—2	
90	8	175	+5	
91	5	171	—4	
92	3	166	—5	
93	0	...	...	
94	3	165	...	
Total	299	179.0	—26	(for cephalic index 73-92)
Average			—1.37	
Weighted index			—1.00	

TABLE 5

Influence of Position in the Range Upon Value of Change at Interval (Based on Tables 2-4)

GROUP	RANGE AND CHANGES AT INTERVAL					
	First Third		Second Third		Last Third	
	Range	Value	Range	Value	Range	Value
Tenerife	70-74	+1	75-78	—4	79-83	+1
Merovingian	67-76	—8	77-84	—8	85-93	+1
Greifenberg	73-79	—12	80-86	—7	87-93	—7

TABLE 6

Lag of Skull Length Against Cranial Index for the Same Range of Cranial Index in the Above Series

SERIES	LAG OF SKULL LENGTH FOR RANGE OF CRANIAL INDEX 72-82		
Tenerife	—0.54	—0.21	weighted index for entire series
Merovingian	—0.65	—0.64	
Greifenberg	—0.93	—0.70	

TABLE 7

Relation Between Head Width and Cephalic (or Cranial) Index in Adult Males in Groups of Northwestern Europe (From Data in W. Scheidt, Zeitschrift für Morphologie und Anthropologie, 28: 30, 72, 78, 40, 1930)

REGION	NO. OF GROUPS		AVERAGE CHANGE IN CEPHALIC INDEX FOR EACH INCREMENT OF 1 MM. IN HEAD WIDTH
		Living	
British Isles	38		+0.36
Iceland and Norway	43		+0.40
Norway (Oesterdal and Gudbrandsdal)	8		+0.60
Norway	13		+0.77
		Skulls	
British Isles	10	Males	+0.51
British Isles	10	Females	+1.03

We plotted cephalic index against head width in a series of New Guinea adult males, and found an average increase in cephalic index of +0.85 for each increment of 1mm. in head width (range of head width, 127-160, of cephalic index, 71.4-84.2 for lower and upper limits of head width). To test lag between groups of fairly homogeneous population we analyzed the relation between head width and cephalic (or cranial) index in living males and in skulls of males, in portions of Northwestern Europe, with the results shown in Table 7.

LAG ON STATURE

A classification of 336 English males over 20 years of age (R. Martin, I, 331) shows an average lag of index $\frac{\text{Head size}}{\text{Stature}}$ of —0.05 for each increment of 1 mm. in stature (head size estimated as the cube root of length × width × height). Thus, though absolute head size increases with stature, relative head size decreases, that is, lags behind stature, when selection is made on the basis of stature.

A series including seven groups of German adult males and one group of Germans in the American army, shows an intergroup lag of body weight against stature. The index $\frac{\text{Body weight}}{\text{Stature}}$ has an average decrease for these groups of —0.004 for each increment of 1 mm. in stature. For the relations of other body dimensions to increases in stature we have computed (Table 8) the indices of lag or of acceleration in six groups of selected adult German males, consisting of 1505 gymnasts, 1562 pugilists, 94 wrestlers, 65 boxers, and 219 actors, a total of 3,445. These groups are, of course, not samples of the general population. They were selected by Bach, whose data we utilized, primarily to show differences in body build in these respective groups. Presumably, therefore, they do not show the normal lag of these respective dimensions against stature.

When the index $\frac{\text{Arm span}}{\text{Stature}}$ is plotted against stature in a series of 153 adult male Melanesians, of the Northwest Coast of New Guinea, there is an acceleration of span-stature index of +0.01, as shown in Table 9.

In the series of Table 9 the shortest group has the lowest arm span-stature index, that is, the least relative arm span, and the tallest group has a relative arm span greater than that of the two groups, in order,

TABLE 8

Lag in Selected Groups of Adult Male Germans
(Bach, Zeitschrift für Konstitutionslehre, 12: 469-522, 1925-1926)

INDEX	LAG AGAINST STATURE	(AVERAGE FOR 1 MM. INCREMENT IN STATURE)
$\frac{\text{Shoulder width}}{\text{Stature}}$	—0.06	
$\frac{\text{Weight}}{\text{Stature}}$	—0.001	
$\frac{\text{Stem length}}{\text{Stature}}$	—0.09	
$\frac{\text{Chest circumference}}{\text{Stature}}$	—0.12	
$\frac{\text{Pelvic width}}{\text{Stature}}$	+0.01	
$\frac{\text{½ Shoulder width + ½ Pelvic width}}{\text{Stature}}$	—0.03	
$\frac{\text{Leg length}}{\text{Stature}}$	+0.10	
$\frac{\text{Arm length}}{\text{Stature}}$	0.00	

TABLE 9

Relation Between Stature and Arm Span in Adult Male Melanesians on the Northwest Coast of New Guinea
(From Data in Rudolf Pöchs Nachlass, Serie A., II. Band, 172ff., Wien, 1930)

NO.	RANGE	MEAN STATURE	MEAN $\frac{\text{ARM SPAN}}{\text{STATURE}}$	RANGE	CHANGE AT INTERVAL
5	1330-1391	1369	103.1	100.0-105.2	....
34	1400-1497	1456	107.5	98.9-110.4	+4.4
67	1500-1597	1557	105.6	99.7-113.2	—1.9
40	1600-1686	1636	105.3	98.8-109.0	—0.3
7	1700-1750	1718	106.6	102.8-108.1	+1.3
Total	(153)				+3.5
Average acceleration of arm span-stature index for 1 mm. of stature					+0.01

below it in stature. These results may be due to chance, since there is a small number of cases in the shortest and tallest groups. The fairly high correlation between stature and arm length, which has been found in European groups, might easily lead to such results when small numbers of individuals are compared. The middle three groups, which include 34 or more individuals in each group, show a decrease in relative arm span with increase in stature. For 43 individuals of the above group the acceleration of index $\frac{\text{Total length of right arm}}{\text{Stature}}$ against 1 mm. increment in stature is +0.01. There is, therefore, a trend toward relatively greater length of arm in terms of stature, from the shortest to the tallest groups; that is, the taller the individual, the relatively longer is his arm in relation to stature. The results are probably explainable by the fact that there is a high correlation between arm length and leg length, and that increase in leg length is largely responsible for increase in stature, with a lag in head height and in trunk length. In that case, arm length might increase in greater proportion than would stature, though, presumably, not in greater proportion than would leg length.

For 38 individuals the intermembral index shows a close relation to stature, having an acceleration upon stature of +0.002. The acceleration of intermembral index upon leg length is almost the same, namely, +0.003. The number of cases is so small, however, and the intercorrelations of stature, leg length, arm length, are relatively so high, that no importance can be attached to these specific values. They indicate, however, a very small degree of lag as between these respective dimensions.

INTERGROUP LAG

In order to test the lag between groups of racially homogeneous type from different localities, we arranged the data of Rouma on Cholo, Quichua, and Aymara, Indians, adult males, of the highlands of Peru. With the exception of one additional group in the first comparison, each comparison is based upon seven groups. There are 25 individuals in each of six groups, and 11 individuals in one group.

The results are presented in Table 10.

An examination of Table 10 shows that, although the number of individuals in the respective groups is small, the principle of lag, sometimes expressed in converse form as acceleration of index, holds in every instance. Lag, therefore, is not merely an intragroup phenom-

TABLE 10

Lag in Seven Local Groups of Adult Male Peruvian Indians
(Data from Rouma, Bulletin et Mémoires de la Société d'Anthropologie de Bruxelles, 32: 31ff., 1913)

INDEPENDENT VARIABLE	RANGE	DEPENDENT VARIABLE	RANGE FOR CORRESPONDING VALUES OF INDEPENDENT VARIABLE	AVERAGE CHANGE FOR 1 UNIT OF INDEPENDENT VARIABLE
Head width	144-153	Cephalic index	77.3-81.7	+0.49
Head height (auricular)	119-131	Height-length index	66.0-70.9	+0.41
Head height (auricular)	119-131	Height-width index	78.6-87.5	+0.74
Bizygomatic diameter ..	136-144	Head width / Face width	94.3-94.7	+0.07
Bizygomatic diameter ..	136-144	Facial index	71.3-75.7	+0.55
Nasal height	50-53	Nasal index	77.0-70.5	—2.17
Stature	1550-1637	Vital index	55.4-53.1	—0.03
Length of arm	665-712	Arm length-stature index	32.9-44.2	+0.19
Leg length	733-802	Leg length-stature index	42.9-42.3	—0.01
Arm length-stature index	32.9-44.4	Leg length-stature index	42.9-47.2	+0.38
Trunk length	487-559	Trunk length-stature index	29.7-34.7	+0.07
Length of foot.....	241-253	Width of foot / Length of foot	42.4-37.6	—0.40
Length of foot.....	241-253	Length of foot / Stature	15.5-15.4	—0.01

enon, but, within limits, at least, an intergroup phenomenon as well. Especially interesting, in view of the findings with regard to New Guinea natives, are the interrelations between arm length, leg length, and stature. When length of arm is selected, stature lags slightly, that is, the index $\frac{\text{Arm length}}{\text{Stature}}$ rises; when leg length is selected, the index $\frac{\text{Leg length}}{\text{Stature}}$ lags, though the lag is only —0.01, as compared with an acceleration of +0.19 for arm-stature index against arm length. When leg-length stature index is plotted against arm length-stature index, the former has an acceleration of +0.38, that is, leg length becomes a relatively larger component part of stature as stature decreases in relation to arm length.

This, again, is an instance of the high correlation between leg length and arm length. Conversely, when trunk length is selected, trunk length-stature index accelerates only +0.07, as compared with the above higher values for arm length against arm length-stature index, and of arm length-stature index against leg length-stature index. One notes, too, that the index $\frac{\text{Length of foot}}{\text{Stature}}$ shows much less lag (—0.01) than does the index $\frac{\text{Width of foot}}{\text{Length of foot}}$, when both are measured against increments in length of foot.

IMPLICATIONS OF LAG FOR STATISTICAL PROCEDURE AND FOR COMPARATIVE STUDIES

The presence of lag suggests that for most anthropometric work the linear correlation (r) is not the best measure of relationship. Where lag is present the η correlation formula will, presumably, show a closer relation between the two variables than is revealed in the r relationship. Since, in most biometric dimensions, X lags on Y, and Y on X, it follows that the relation between X and Y is not linear—their perfect correlation could not be a straight line.

The fact that most variables of biometric dimensions, when one is not inclusive of the other, show low r's, is due, in part, to the fact that each dimension lags upon the other. Moreover, much anthropometric procedure is concerned with pattern, that is, with index, or proportion. The index, that is, the pattern, may, however, remain unchanged in a series and yet the r will not be 1. Thus, if $xy = (\text{sigma } x)\ (\text{sigma } y)$, then, if x is less than or greater than y, $(x + (\frac{1}{3}x))\ \ (y + (\frac{1}{3}y))$ will

not equal (sigma x) (sigma y), although the proportion between the respective products, x and y, remains the same. Even though the index remains the same, the r will change unless the deviations are the same absolute (rather than the same relative) amount. The r, therefore, will not demonstrate to what extent the pattern, that is, the index, changes. When, however, the coefficients of variation of the respective variables have the same value, the r will be a measure of the variability of the index, that is, of the variability of the ratio of x to y. Although the coefficient of variation is not contained directly in the r, it is, as a matter of fact, to some extent reflected in it, since in biometric data, the larger dimensions almost always have the larger standard deviations. There is, therefore, a positive correlation between the standard deviation of $\frac{x}{y}$ and the r of XY. The standard deviation of the cephalic index is, for example, an indication of the value of the r of head width-head length.[2]

The phenomenon of lag is hidden under the usual statistical descriptions of series, which utilize primarily proportions, means, and linear correlations. A linear correlation of a dimension with the index of which it is a component is, however, a measure of lag, though linear correlations of dimensions do not give any intimation of lag. Thus the lag of head length upon head width, and conversely, is indicated in correlations of head width and head length, respectively, with cephalic index. These correlations are appreciably high both within a group and as between groups. Each is higher, in two series tested, than the correlation between head length and head width, as indicated in Table 11.

TABLE 11

Correlations Between Length and Breadth of Skull, and Between Length and Cranial Index, and Width and Cranial Index

NO.	SERIES	LENGTH-BREADTH	LENGTH-C. I.	BREADTH-C. I.	AUTHORITY
59	ethnic groups	+.43	—.76	+.95	Morant
900	Ancient Egyptian males	+.40	—.49	+.59	Pearson and Davin

[2] See Ruth Sawtell Wallis, in *Human Biology*, Vol. 6, pp. 308-323, 1934.

The higher correlation of cephalic index with width than with length is largely due to the fact that a variation of the same absolute quantity in breadth affects the cephalic index more than that amount of variation in length (due to the smaller dimension of breadth). This difference is reflected in the higher index of acceleration of cephalic index against head width, as compared with the index of lag of cephalic index against head length.

A similar fact probably accounts for the different values of lag at different points of the range.

Our analysis of the rates of lag in three series of skulls, using head length and cephalic index, showed no consistent differences in rate of lag at different points of the series. We analyzed the rates of lag, or of acceleration, in the Peruvian Indian series, cited above. The total for all series is given in Table 12. (Total acceleration, when this characterizes a series, is treated as lag. A minus sign indicates that the change is in a direction contrary to that of the total of the series, whether this is lag or acceleration.)

TABLE 12

Total Lag, or Acceleration, of Index (Dependent Variable) for Each Third of Range in the Above Series of Peruvian Indian Groups, in Order of Increments of the Independent Variable

INDEPENDENT VARIABLE	DEPENDENT VARIABLE (INDEX)	1ST 3RD	2ND 3RD	3RD 3RD
Head width	Cephalic	5.0	4.0	—3.7
Head height (auricular)	Height-length	3.9	0.0	1.0
Head height (auricular)	Height-width	2.9	3.4	2.6
Bizygomatic diameter	Head width-face w.	0.1	—1.2	1.5
Bizygomatic diameter	Facial	5.4	3.0	—4.1
Nasal height	Nasal	3.0	3.3	0.2
Stature	Vital	—0.8	2.6	4.5
Length of arm	Arm-stature	9.4	3.0	1.1
Arm length-stature index	Leg length-stature	6.0	—1.6	—0.1
Leg length	Leg length-stature	1.1	—2.4	1.9
Trunk length	Trunk length-stature.	4.1	—0.3	1.1
Length of foot	$\frac{\text{Width of foot}}{\text{Length of foot}}$	0.2	1.4	3.4
Length of foot	$\frac{\text{Length of foot}}{\text{Stature}}$	0.1	0.1	—0.1
Total		3.2	1.6	1.3

There is a predominance of lag in the first third interval of the range of the independent variable. Its value predominates over that of either of the other third intervals in 6 of 13 cases, over the second third in 8 cases, and over the last third in 9 cases, the average value being double that of either of the other third intervals. Although the average lag in the third interval is less than that of the second, it is below the value of the second interval in only 6 of the 13 cases. The decreasing lag of index with increasing value of independent variable is probably due to the fact that an absolute unit of increase, such as 1 mm., bears a larger proportion to the mean of the independent variable in the lower values than in the higher and so tends to offset the increments of the dimension which is measured against it in the index which comprises the dependent variable. An adequate test of this point demands more data than we have assembled.

In so far as lag is a biometric characteristic it must be taken into account in any comparative study which aims to ascertain group characteristics due to other factors. During growth, for example, there will, of necessity, be lag in all other dimensions plotted against the one which is increasing most rapidly. If the greatest rate of increase is in stature, any other dimension not a component of stature will lag. Thus differences in proportions of respective dimensions to stature in various age groups will not be a characteristic of age groups as such, but merely a biometric characteristic of stature. They will be attributable specifically to age only when the proportions are of significantly different value than are associated with that value of stature at other age levels; though there are, of course, characteristic age proportions.

R. S. Wallis has shown, for example, that when stature and age are equalized for the age period 2-6 years, the sex differences in arm-leg length index are almost uniformly less than when stature alone is considered. Her data are given in Table 13.

Thus, almost uniformly, up to the age of 6, the sex difference in this index is less when age and stature are equalized than when stature alone is equalized. Age, therefore, plays a part in determining the value of the index. In the case of both boys and girls, for each stature group the index is higher, almost uniformly, in the younger group than in the older group. Thus age has a differential influence.

The general trend, however, is for the index to decrease with age. The younger group at a given stature level, therefore, tends to maintain the infantile type of index to a greater extent than does the older

TABLE 13

Arm-leg Length Index, Boys and Girls (R. S. Wallis, American Journal of Physical Anthropology, 16: 184-185, 1931)

STATURE	NUMBER	BOYS	NUMBER	GIRLS	DIFFERENCE	AGE	NUMBER	BOYS	NUMBER	GIRLS	DIFFERENCE	MEAN SEX DIFF. FOR AGE GROUPS AT SAME STAT. LEVEL
86- 90	30	122.0	31	117.2	4.8	2	20	121.9	20	118.5	3.4	
						3	8	118.8	10	116.6	2.2	2.8
91- 95	52	118.5	71	115.1	3.4	2	11	120.2	6	117.0	3.2	
						3	36	118.5	58	114.5	4.0	
						4	5	115.0	7	112.3	2.7	3.3
96-100	59	115.8	63	112.4	3.4	3	31	116.7	29	114.6	2.1	
						4	27	114.7	29	111.4	3.3	2.7
101-105	69	113.6	71	110.4	3.2	3	7	117.4	3	112.0	5.4	
						4	46	113.2	42	110.3	2.9	
						5	16	111.8	24	108.8	3.0	3.8
106-110	102	111.3	103	108.1	3.2	4	26	113.1	11	109.9	2.2	
						5	57	110.5	69	108.7	1.8	
						6	18	110.8	19	107.6	3.2	2.4
111-115	98	109.3	120	106.5	2.8	5	41	110.0	23	107.1	2.9	
						6	44	108.2	61	105.6	2.6	
						7	13	108.3	27	105.9	2.4	2.6
116-120	139	107.6	110	104.5	3.1	6	63	107.2	51	105.4	1.8	
						7	53	106.9	40	104.8	2.1	
						8	13	106.6	13	104.8	1.8	1.9
121-125	99	106.1	107	103.4	2.7	6	11	106.8	3	103.7	3.1	
						7	51	106.7	48	103.1	3.6	
						8	28	106.4	36	103.7	2.7	3.1
Mean					3.3	.....					2.8	2.8

age group at that stature level, whereas the older age groups show the usual age trend in index in spite of lag in stature. Thus age status, at a given stature level, is highly correlated negatively with arm-leg length index. That age is, nevertheless, not the most important factor in determining the value of this index is shown by the fact that when arm-leg length index of boys and girls of the above series is compared by age groups the mean difference is less than when stature alone is

TABLE 14

Sex Differences in Means of Arm-leg Length Index by Age Groups, and by Age Groups With Stature Equalized (R. S. Wallis, Op. cit., p. 182)

AGE GROUP IN YEARS	NO. BOYS		NO. GIRLS		DIFFERENCE	DIFFERENCE WHEN STATURE IS EQUALIZED
2	39	122.0	38	119.0	3.0	3.6
3	82	118.3	103	113.8	4.5	3.4
4	98	114.4	111	111.6	2.8	2.8
5	121	111.1	109	108.7	2.4	2.8
6	148	108.2	134	107.1	1.1	2.7
7	148	106.4	138	104.9	1.5	2.7
8	137	104.9	120	103.6	1.3	2.2
Mean					2.4	2.9

equalized for the respective groups, and is less than when stature and age are equalized. (Table 14.)

Though age plays a significant part in determining the value of the arm-leg length index, its rôle as a factor of sex differentiation is not as potent as that of age in combination with stature, or as that of stature alone. The potency of age, as against age and stature, seems more marked in the age period 2-5 years than in the age period 6-8 years. The mean sex differences for age alone are the same as the mean sex differences for age and stature for the age period 2-5, whereas they are for each year group of ages 6-8 only about one-half the difference for age and stature combined.

A weighting of anatomic lag is necessary in order to ascertain sex differences which are properly attributable to the factor of sex. It is, for example, commonly stated that women in a given group have a higher cephalic index than do males. They have, however, absolutely shorter heads. By virtue of the principle of anatomic lag we would, therefore, expect them to have relatively wider heads, that is, to have a higher cephalic index. In so far as cephalic index is a function of head length, it follows that the fundamental sex difference is in absolute length of head. Only when the cephalic index is significantly different between males and females having the same absolute head length (or head width) would cephalic index as such be a true sex trait as distinguished from a mere biometric trait. Since, moreover, in each sex,

head length is positively correlated with stature, it follows that sheer difference in head length in the two sexes is not a sex trait as such, but merely a biometric trait. The sex significance will appear only when account is taken of respective statures, that is, when stature is equalized, or weighted.[3]

Since lag applies to certain dimensions, it follows that it applies also to certain proportions, or indices, whether they are highly correlated or not. We have not tested the lag in interrelations of indices.

That lag does not hold unqualifiedly for all parts of the body is indicated in the data of Table 15 on pelvic dimensions and proportions.

In most of the above dimensions, the pelvis shows little respect for lag when means of group values are compared. Thus in the above groups breadth of os innominatum increases more rapidly than height,

TABLE 15

Indices of Lag, or of Acceleration, in Means of Group Values in Pelvic Dimensions and Indices (E. A. Hooton, Indians of Pecos Pueblo, p. 173. New Haven, Yale University Press, 1930)

NO. OF GROUPS	DIMENSION, AND RANGE FOR MALES	INDEX	AVERAGE CHANGE IN INDEX FOR EACH UNIT INCREMENT OF INDEPENDENT VARIABLE	
			Males	Females
5	Height of os innom., right, 205.0-220	$\frac{\text{Breadth}}{\text{Height}}$	+0.01	+0.21
5	Same, left, 205.0-221	$\frac{\text{Breadth}}{\text{Height}}$	+0.01	+0.35
6	Height of sacrum, 104.7-109.5	$\frac{\text{Breadth}}{\text{Height}}$	+0.01	—1.58
10	Height of os innom. (pelvic), 200-220.6	$\frac{\text{Height}}{\text{Breadth}}$	+0.26	+0.10
10	Anterior-post. diam. of pelvis, 95.56-107	$\frac{\text{Ant. post. diam.}}{\text{Lateral diam.}}$	—0.92	+1.05

[3] As was pointed out many years ago by Pearl. See Raymond Pearl, "Biometrical Studies on Man, I. Variation and Correlation in Brain Weight," *Biometrika*, 4: 13-104, 1905-1906, and Studies in Human Biology, pp. 31-32, *Baltimore*, Williams and Wilkins, 1924.

in both sexes, when height is selected. Since this holds for both right and left ossa innominata, the type result in these groups is probably not due to chance. Similarly, when height of sacrum is selected, breadth increases faster than height in the male, though it lags considerably in the female. When height of os innominatum is selected, breadth, in each sex, lags. Lateral diameter, in brim index, is accelerated against antero-posterior diameter in males, but shows considerable lag in females. In four of the five indices females show higher values in rate of change in dependent variable than do males, and in two indices the direction of the change is reversed in the two sexes.

In conclusion, we may observe that the application of anatomic lag to the determination of race differences is obvious. In so far as lag applies not only within a group, but also, as we have shown is sometimes the case, between groups, when these are treated as statistical units, then some traits of groups are, to a degree at least, biometric rather than fundamentally racial. Thus most long headed peoples have a low cephalic index, whether they are Neanderthals, Australians, or Caucasoids. Again, to the extent that cephalic index is a function of absolute head length, it is not fundamentally racial but merely a biometric trait associated with long-headedness. And, again, to the extent that length of head is a function of stature, the "race" difference in cephalic index is essentially biometric. Anatomic lag, therefore, answers a few questions, and questions many answers.

THE CALCIFICATION OF THE FIRST COSTAL CARTILAGE AMONG WHITES AND NEGROES

BY NICHOLAS MICHELSON, M. D.

(From the Department of Anthropology, Columbia University)[1]

THE following study of the calcification of the costal cartilages has been confined to the upper left and right thoracic ribs. Roentgenograms of 5,098 healthy individuals were examined and classified. The criterion applied for measuring the extent of calcification was the same as used by Dr. G. Ernst [2] in an investigation dealing with the process of calcification in all the costal cartilages. In order to obtain a picture of the rhythm with which calcification progresses with the increase of age, a somewhat arbitrary method has been used which makes it possible to express the physiologic process by means of numerical values. The amount of calcification has been defined as: "None," "Minimal," "Medium" and "Maximal."

I. No calcification.—If there is no calcification present the film shows a gap between the anterior extremity of the rib and the sternum, since the cartilage which lacks ossification does not cast a shadow on the plate.

II. Minimal calcification.—In beginning calcification a discrete oval surrounds the region corresponding to the junction of the rib with the cartilage (Köhler).[3] From this concentric segment the calcification then proceeds towards the sternum. This being the rule, the mode of beginning calcification may be subdivided into the following twelve types which may either occur symmetrically or asymmetrically; that is to say in some individuals the amount and form of the calcific deposits may be equal on the left and right sides, and in other persons all the

[1] Investigation carried on under the auspices of the Council for Social Research.

[2] G. Ernst. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 39: 485-494. March, 1929.

[3] Alban Köhler. Grenzen des Normalen und Anfänge des Pathologischen im Röntgenbilde, 6th ed. (1931), p. 296.

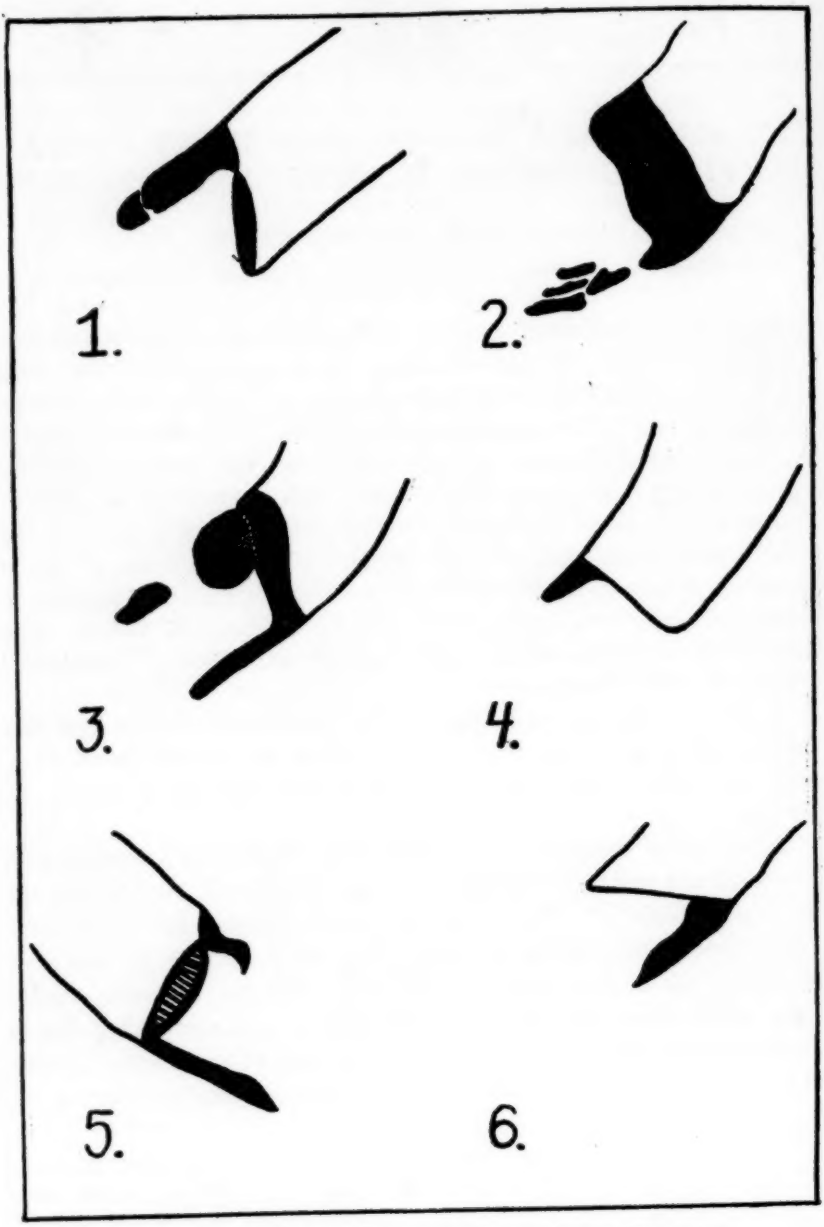
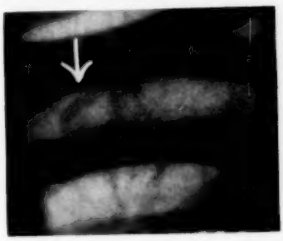


FIG. 1. TYPES OF CALCIFICATION OF FIRST COSTAL CARTILAGE



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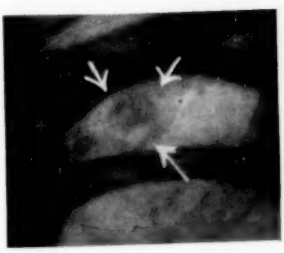

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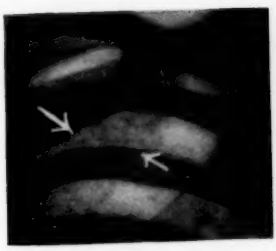

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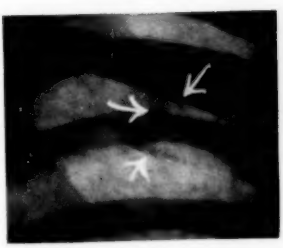

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6.

PLATE I

TYPES OF CALCIFICATION OF FIRST COSTAL CARTILAGE

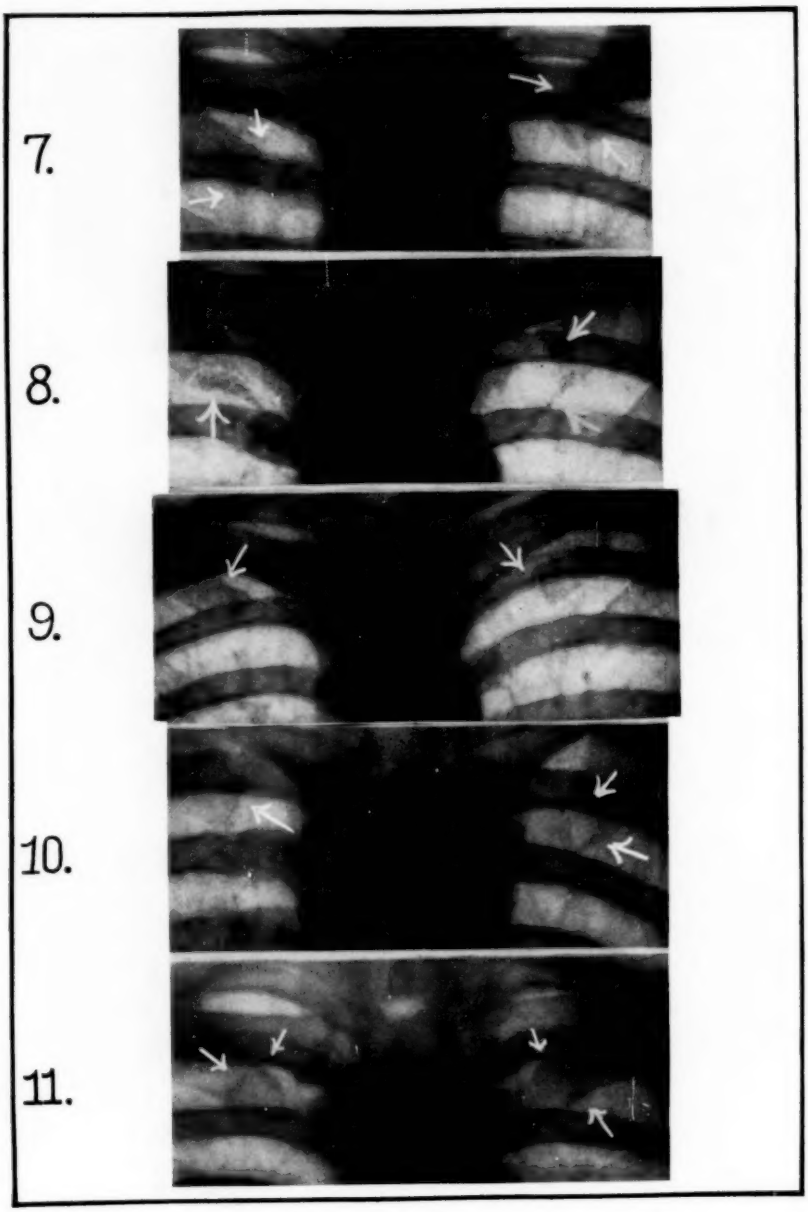


PLATE II

TYPES OF CALCIFICATION OF FIRST COSTAL CARTILAGE, RIGHT AND LEFT

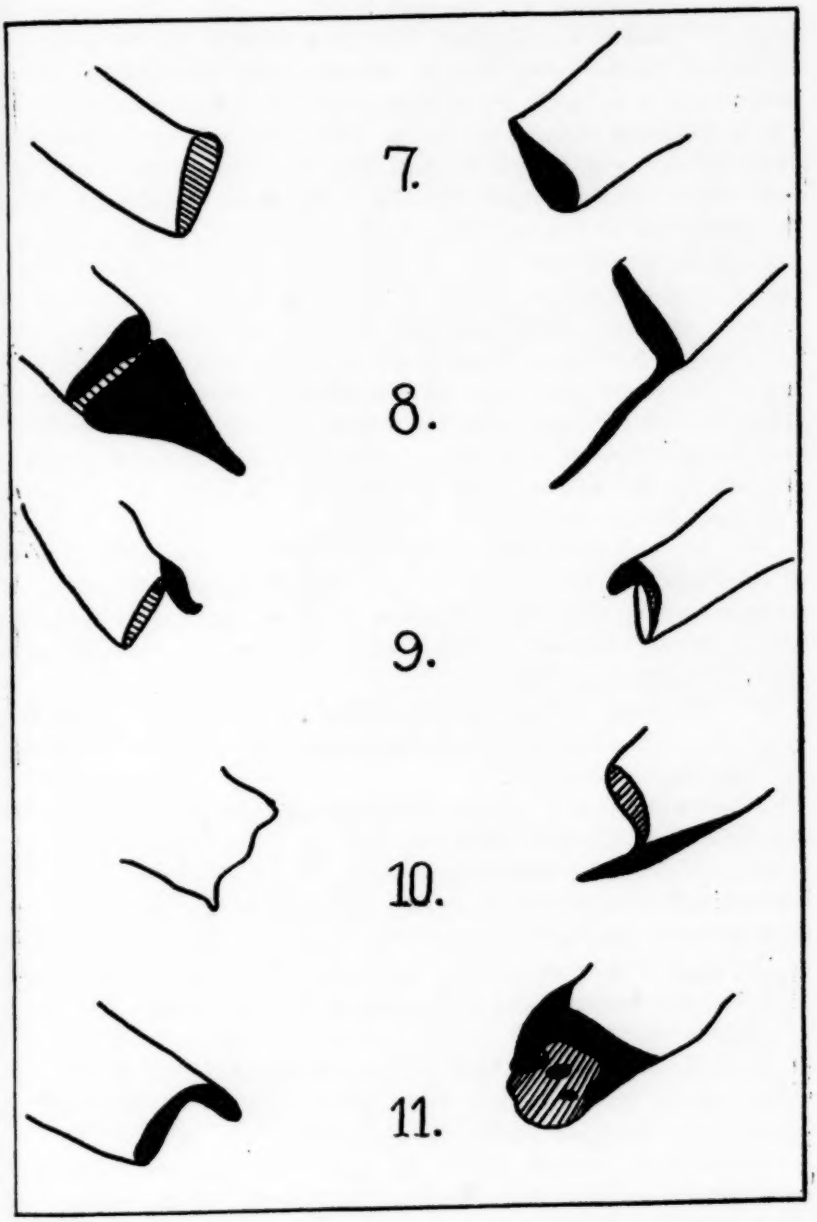


FIG. 2. TYPES OF CALCIFICATION OF FIRST COSTAL CARTILAGE, RIGHT AND LEFT

possible combinations may be seen right and left. Thus under the heading "Minimal Calcification" have been classed: (1) an oval; (2) an oval with a horizontal spur or line extending from the rib's lower border; (3) a vertically serrated or serpentine termination of the rib; (4) a horizontal spur or line at the lower edge without a discernible oval; (5) an oval with horizontal lines or spurs at the lower and upper edges; (6) a compact segment at the costal termination; (7) a horizontal spur or line extending from the upper edge; (8) a compact segment with horizontal spurs or lines at the upper and lower edges; (9) an oval with a spur or line at the upper border; (10) a compact segment with horizontally arranged shells at the lower border; (11) horizontal lines or spurs at upper and lower borders; and finally, (12) any of the enumerated types on one side and no calcification on the opposite costal cartilage. The line engravings correspond to the photographic-reproductions with the corresponding numbers. The figures representing the various types are indicated in Table 1. (Table 1, Plates and Figs. 1 and 2.)

III. Medium calcification.—For a condition in which the progress of calcification of the cartilage is more marked and almost reaches the sternum or does reach the sternum on either the upper or lower border while being still minimal on the opposite side, the term "medium calcification" has been employed.

IV. Maximum calcification.—Calcifications causing a dense continuity from the rib to the sternum have been assigned to the final group, the "maximal" calcification.

In order to ascertain whether different examiners would agree on the classification of the same plates, Dr. Ernst P. Boas and myself grouped a series of about 200 plates independently and comparison of the data showed that they coincided, excepting for a few border line cases. Another series of 500 plates was scrutinized in a preliminary study together by Dr. H. T. Pessar and myself; again we were in complete agreement regarding the nomenclature to be adopted for the manner and degree of calcification.

In order to avoid any kind of bias, the age and race of the individual whose Roentgenogram was studied were extracted from the files after the classification had been completed.

The habitus of the chest could not be taken into account. Two main racial groups were studied: Whites and Colored. Porto Ricans, who were nearer to the Whites than to the Colored, were included in a

TABLE 1

Types of the Beginning Calcification of the First Costal Cartilage

	TYPE	ASYMMETRIC CALCIFICATION Right	ASYMMETRIC CALCIFICATION Left	SYMMETRIC CALCIFICATION Right and left	NUMBER OF ILLUSTRATION
1.	Oval	29	16	57	Fig. 2—7 right
2.	Oval with spur or line at lower edge	5	11	38	Fig. 2—10 right
3.	Corroded or sharp serpentine edge	5	3	4	Fig. 2—10 left
4.	Spur or line at lower edge	6	7	4	Fig. 1—6 right
5.	Oval with spur or line at upper and lower edges	0	0	3	Fig. 1—5
6.	Compact mass	6	11	1	Fig. 2—7 right
7.	Upper spur or line	0	1	1	Fig. 1—4
8.	Compact mass with spur or line at upper and lower edges	0	1	0	Fig. 2—11 right
9.	Oval with spur or line at upper edge	1	0	2	Fig. 2—9 right
10.	Compact mass with flakes at lower edge	1	1	0	Fig. 1—2
11.	Line or spur at upper and lower edges	0	1	0	Fig. 2—11 right and Fig. 1—5
12.	No calcification	14	15	0	.....
	Number of persons	67	67	110	.....
	Number of cartilages	67	67	220	.....

Total persons 177
Total cartilages 354

special mixed group in which the Colored predominated. The sexes were tabulated separately.

The relationship to disease was not an issue in this investigation, since pathological cases were excluded. Whether the frequency with which lues occurs among the Colored may be a factor in producing calcification earlier than among the Whites is an open question. Frank Riebel has suggested such a possibility.[4]

Roentgenograms of the first costal cartilage taken at regular intervals would permit us to follow up the progress of calcification with increasing age, but at present we do not possess records of the same person covering long periods of time. Therefore, I had to compare the findings on groups of individuals of different ages. Calcification of the first costal cartilage does not seem to begin under eleven years of age, except in extremely rare instances. We do not know anything about hereditary influences. As a curiosity I cite the case of a Negress, 62 years of age, with medium calcification, while her daughter, 29 years of age, showed maximum calcification. In the case of a pair of female Colored twins, 18 years of age, one girl showed minimal, the other no calcification.

Only dorsoventral Roentgenograms were used for this study.[5] All films were taken by the same technique, namely, the one customary at the Tuberculosis Clinics of the Board of Health, in other words, we are dealing with standard lung pictures. The sources of our material are: Dr. Ernst P. Boas, who permitted the use of films obtained from about 200 private patients; the Tuberculosis Clinics of the Board of Health at the Harlem Hospital (Chief: Dr. John A. Heitlinger) and the Mott Haven Clinic (Chief: Dr. H. T. Pessar), and, finally, the Roentgenographic Department of the Harlem Hospital (Chief: Dr. William Snow), all in New York City. Miss Mary Lloyd, Miss Christine McGrath, and Miss Bertha Sigales of the Social Service Department at the Harlem Hospital have furnished the data on all the Colored persons. Dr. Jacob Goldberg of the New York Tuberculosis and Health Association, Dr. D. C. Martin of the Board of Health and the administration of the Harlem Hospital made the work possible by giving access to the records. The tabulations were made by Miss Bertha Cohen.

[4] Frank Riebel. Ossification of the Costal Cartilages. *American Journal for Roentgenology and Radium Therapy*, January, 1929, XXI, 44.

[5] On account of the transfer right and left are reversed on Plates I and II.

I take this occasion to thank the above mentioned for their co-operation.

Of the persons entered into the list of the white population, 2,000 are food handlers. The majority of all the cases are persons who frequent clinics. The social status of both sexes is equal for each racial group; however, the Colored constitute a poorer class than the Whites.

All the figures were arranged in a chronological order covering five year periods.

In order to express the rhythm of calcification during the advance of life numerically, I have arbitrarily chosen symbolic equivalents, namely, "Zero" if no calcification was present, "Thirty" for minimal calcification, "Sixty" for medium, and "Ninety" for marked or maximum calcification. These symbols were used as values for the percentile

TABLE 2a

Calcification of First Rib—White Males

AGE	ABSOLUTE NUMBERS AND PER CENT CALCIFICATION								TOTAL CASES	AVERAGE PER CENT CALCIFICATION
	0		30		60		90			
6 to 10 yrs.	54	*100.0*	0	*0*	...	...	...	...	54	0
11 to 15....	43	*82.7*	9	*17.3*	0	*0*	...	...	52	5.2
16 to 20....	83	*41.7*	114	*57.3*	2	*1.0*	0	*0*	199	17.8
21 to 25....	22	*8.9*	159	*64.1*	66	*26.6*	1	*0.4*	248	35.6
26 to 30....	0	*0*	112	*46.5*	126	*52.3*	3	*1.2*	241	46.4
31 to 35....	0	*0*	32	*16.6*	126	*65.3*	35	*18.1*	193	60.5
36 to 40....	1	*0.4*	16	*6.6*	143	*59.3*	81	*33.6*	241	67.8
41 to 45....	..	...	7	*3.4*	104	*51.0*	93	*45.6*	204	72.6
46 to 50....	..	...	1	*0.6*	66	*42.0*	90	*57.3*	157	77.0
51 to 55....	..	...	..	...	27	*30.0*	63	*70.0*	90	81.0
56 to 60....	..	...	..	...	12	*25.0*	36	*75.0*	48	82.5
61 to 65....	..	...	..	...	1	*7.1*	13	*92.9*	14	87.9
66 to 70....	..	...	..	...	..	...	13	*100.0*	13	90.0
71 and over	..	...	..	...	..	...	4	*100.0*	4	90.0

1,758 total cases.

frequencies of absent, minimal, medium and maximum calcification respectively. Treating in this manner the values of the four degrees of calcification, average values for each age group were determined. It would seem that the value 30 for minimal calcification is too high, because the difference between "minimal" and "medium" seems greater than that between "non" and "minimal," but an arbitrary lowering of the value 30 for "minimal" to 20 would not materially change the results. The other approximations, 60 for "medium" and 90 for "maximum" calcification are well balanced. The "maximal" group was not called 100, because it contains cases in which the calcification was not quite complete.

Table 1 and Plate I are devoted to the morphology of beginning calcification in the first costal cartilage. Of the eleven forms of early

TABLE 2b

Calcification of First Rib—White Females

AGE	ABSOLUTE NUMBERS AND PER CENT CALCIFICATION								TOTAL CASES	AVERAGE PER CENT CALCIFICATION
	0		30		60		90			
6 to 10 yrs.	44	*100.0*	0	*0*	..	...	..	...	44	0
11 to 15....	40	*76.9*	12	*23.1*	0	*0*	..	...	52	6.9
16 to 20....	149	*54.0*	124	*44.9*	3	*1.1*	..	...	276	14.1
21 to 25....	33	*16.6*	146	*73.4*	20	*10.0*	..	...	199	28.0
26 to 30....	2	*1.2*	113	*65.3*	58	*33.5*	0	*0*	173	39.7
31 to 35....	1	*0.6*	68	*41.7*	87	*53.4*	7	*4.3*	163	48.4
36 to 40....	1	*0.7*	43	*29.7*	96	*66.2*	5	*3.4*	145	51.7
41 to 45....	..	...	21	*21.4*	65	*66.3*	12	*12.2*	98	57.2
46 to 50....	..	...	6	*7.4*	61	*75.3*	14	*17.3*	81	63.0
51 to 55....	..	...	4	*11.4*	22	*62.9*	9	*25.7*	35	64.3
56 to 60....	..	...	..	...	10	*76.9*	3	*23.1*	13	66.9
61 to 65....	..	...	..	...	4	*57.1*	3	*42.9*	7	72.9
66 to 70....	..	...	..	...	..	...	3	*100.0*	3	90.0
71 and over	..	...	..	...	..	...	1	*100.0*	1	90.0

1,290 total cases.

calcification the most frequent one is a circle delineating (Fig. 2—Pl. Ia) the anterior aspect of the rib. The oval together with a horizontal spur or line extending from the lower border of the rib along the cartilage towards the sternum takes the second place in frequency (Pl. Ib). In a series of 177 individuals symmetric calcification occurred decidedly more often than asymmetric.

INCREASE IN CALCIFICATION WITH AGE

Table 2 demonstrates the calcification as found among 3,048 White persons (1,758 males and 1,290 females). As in all other tables the first column contains the cases without any calcification; the second those with minimal, the third with medium, the fourth with maximum calcification. As mentioned before, each figure embraces one quinquennium. The last column represents the increase of an average percentage of calcification with the increase of age. There is a striking difference between the sexes: the men begin at 16 years of age showing more intense calcification than the females, and this quantitative difference continues until the sixty-sixth year when both sexes have reached the maximum calcification. Before the fifteenth year of age there does not seem to be any difference between males and females. At about twenty years of age both sexes undergo their most rapid increase in average calcification. At about 40 years of age the tempo of increase slows down. Each following decennium displays a diminution in the speed of calcification.

It is due to the nature of the phenomenon, that the variability of the degree of calcification is greatest during the middle period of the process when all forms may occur in the same age group.

Ernst as well as some of his predecessors whom he mentions in his well-rounded bibliography, found also the costal cartilages of men to calcify more rapidly than those of women. However, his material is not comparable with mine because I have eliminated disease. Furthermore, Ernst made a general estimate of all the costal cartilages, whereas I have restricted myself to that costal cartilage which may be seen on the film with greatest clearness. Moreover, he did not consider the fact, pointed out by Hrdlička,[6] that the mode of calcification of the first

[6] Ales Hrdlička, Repr. from *Proceedings of the Association of American Anatomists,* Fourteenth Session, December, 1900. Contribution to Osteology, *New York.*

TABLE 3a

Calcification of First Rib

Male Mixed Population Containing 70 Per Cent Colored and 30 Per Cent White Persons—(The Whites are Mainly Porto Ricans)

AGE	ABSOLUTE NUMBERS AND PER CENT CALCIFICATION								TOTAL CASES	AVERAGE PER CENT CALCIFICATION
	0		30		60		90			
6 to 10 yrs.	53	*100.0*	0	*0*	..	...	..	...	53	0
11 to 15....	33	*86.8*	5	*13.2*	..	...	..	...	38	3.9
16 to 20....	10	*45.5*	12	*54.5*	0	*0*	0	*0*	22	16.4
21 to 25....	3	*6.7*	18	*40.0*	23	*51.1*	1	*2.2*	45	44.7
26 to 30....	0	*0*	9	*14.0*	49	*76.6*	6	*9.4*	64	58.6
31 to 35....	0	*0*	4	*6.1*	53	*80.3*	9	*13.6*	66	62.3
36 to 40....	1	*1.5*	3	*4.5*	26	*39.4*	36	*54.5*	66	74.1
41 to 45....	..	...	..	...	16	*36.4*	28	*63.6*	44	79.1
46 to 50....	..	...	..	...	5	*22.7*	17	*77.3*	22	83.2
51 to 55....	..	...	..	...	4	*13.8*	25	*86.2*	29	85.9
56 to 60....	..	...	..	...	4	*23.5*	13	*76.5*	17	82.9
61 to 65....	..	...	..	...	0	0	11	*100.0*	11	90.0
66 to 70....	..	...	..	...	0	*0*	4	*100.0*	4	90.0
71 and over	..	...	..	...	2	*22.2*	7	*77.8*	9	83.3

490 total cases.

TABLE 3*b*

Calcification of First Rib

Female Mixed Population Containing 70 Per Cent Colored and 30 Per Cent White Persons—(The Whites are Mainly Porto Ricans)

AGE	ABSOLUTE NUMBERS AND PER CENT CALCIFICATION								TOTAL CASES	AVERAGE PER CENT CALCIFICATION
	0		30		60		90			
6 to 10 yrs.	48	*100.0*	0	*0*	..	...	..	...	48	0
11 to 15....	46	*75.4*	15	*24.6*	0	*0*	..	...	61	7.4
16 to 20....	31	*46.3*	33	*49.2*	3	*4.5*	..	...	67	17.5
21 to 25....	17	*17.2*	60	*60.6*	22	*22.2*	..	...	99	31.5
26 to 30....	4	*7.4*	24	*44.4*	23	*42.6*	3	*5.6*	54	43.9
31 to 35....	..	...	8	*22.9*	21	*60.0*	6	*17.1*	35	58.3
36 to 40....	..	...	7	*16.7*	27	*64.3*	8	*19.0*	42	60.7
41 to 45....	..	...	1	*4.3*	12	*52.2*	10	*43.5*	23	71.7
46 to 50....	..	...	..	...	11	*64.7*	6	*35.3*	17	70.6
51 to 55....	..	...	..	...	6	*54.5*	5	*45.5*	11	73.6
56 to 60....	..	...	..	...	1	*16.7*	5	*83.3*	6	85.0
61 to 65....	..	...	..	...	1	*14.3*	6	*85.7*	7	85.7
66 to 70....	..	...	..	...	3	*50.0*	3	*50.0*	6	75.0
71 and over	..	...	..	...	1	*12.5*	7	*87.5*	8	86.3

484 total cases.

TABLE 4a

Calcification of First Rib—Colored Males

AGE	ABSOLUTE NUMBERS AND PER CENT CALCIFICATION								TOTAL CASES	AVERAGE PER CENT CALCIFICATION
	0		30		60		90			
6 to 10 yrs.	13	*100.0*	0	*0*	..	...	..	...	13	0
11 to 15....	26	*72.2*	10	*27.8*	0	*0*	..	...	36	8.3
16 to 20....	9	*34.6*	15	*57.7*	2	*7.7*	..	...	26	21.9
21 to 25....	4	*7.0*	28	*49.1*	25	*43.9*	0	*0*	57	41.1
26 to 30....	..	...	16	*17.8*	59	*65.6*	15	*16.7*	90	59.7
31 to 35....	..	...	4	*8.0*	36	*72.0*	10	*20.0*	50	63.6
36 to 40....	..	...	1	*2.1*	22	*45.8*	25	*52.1*	48	75.0
41 to 45....	..	...	..	...	14	*38.9*	22	*61.1*	36	78.3
46 to 50....	..	...	..	...	8	*30.8*	18	*69.2*	26	80.8
51 to 55....	..	...	..	...	1	*7.7*	12	*92.3*	13	87.7
56 to 60....	..	...	..	...	0	*0*	10	*100.0*	10	90.0
61 to 65....	..	...	..	...	1	*50.0*	1	*50.0*	2	75.0
66 to 70....	..	...	..	...	..	...	5	*100.0*	5	90.0
71 and over	..	...	..	...	..	...	1	*100.0*	1	90.0

413 total cases.

TABLE 4*b*

Calcification of First Rib—Colored Females

AGE	ABSOLUTE NUMBERS AND PER CENT CALCIFICATION								TOTAL CASES	AVERAGE PER CENT CALCIFICATION
	0		30		60		90			
6 to 10 yrs.	9	*90.0*	1	*10.0*	..	...	..	...	10	3.0
11 to 15....	35	*76.1*	11	*23.9*	0	*0*	..	...	46	7.2
16 to 20....	42	*43.3*	51	*52.6*	4	*4.1*	..	...	97	18.2
21 to 25....	23	*16.3*	86	*61.0*	32	*22.7*	0	*0*	141	31.9
26 to 30....	3	*2.9*	52	*50.0*	44	*42.3*	5	*4.8*	104	44.7
31 to 35....	1	*1.2*	21	*24.4*	55	*64.0*	9	*10.5*	86	55.1
36 to 40....	2	*2.6*	9	*11.8*	43	*56.6*	22	*28.9*	76	63.6
41 to 45....	..	...	1	*2.9*	17	*50.0*	16	*47.1*	34	73.2
46 to 50....	..	...	2	*8.0*	11	*44.0*	12	*48.0*	25	72.0
51 to 55....	..	...	1	*5.0*	7	*35.0*	12	*60.0*	20	76.5
56 to 60....	..	...	..	...	5	*27.8*	13	*72.2*	18	81.7
61 to 65....	..	...	..	...	1	*25.0*	3	*75.0*	4	82.5
66 to 70....	..	...	..	...	..	...	1	*100.0*	1	90.0
71 and over	..	...	..	...	..	...	1	*100.0*	1	90.0

663 total cases.

rib might take a different morphological course than that in the lower cartilages.

Table 3 contains the figures of a mixed population, the Colored constituting about 70 per cent of the entire series, the other 30 per cent being mainly Porto Ricans apparently White but probably with some Negro admixture (490 males and 484 females). This table shows practically the same values as Table 4 which embraces a separate group

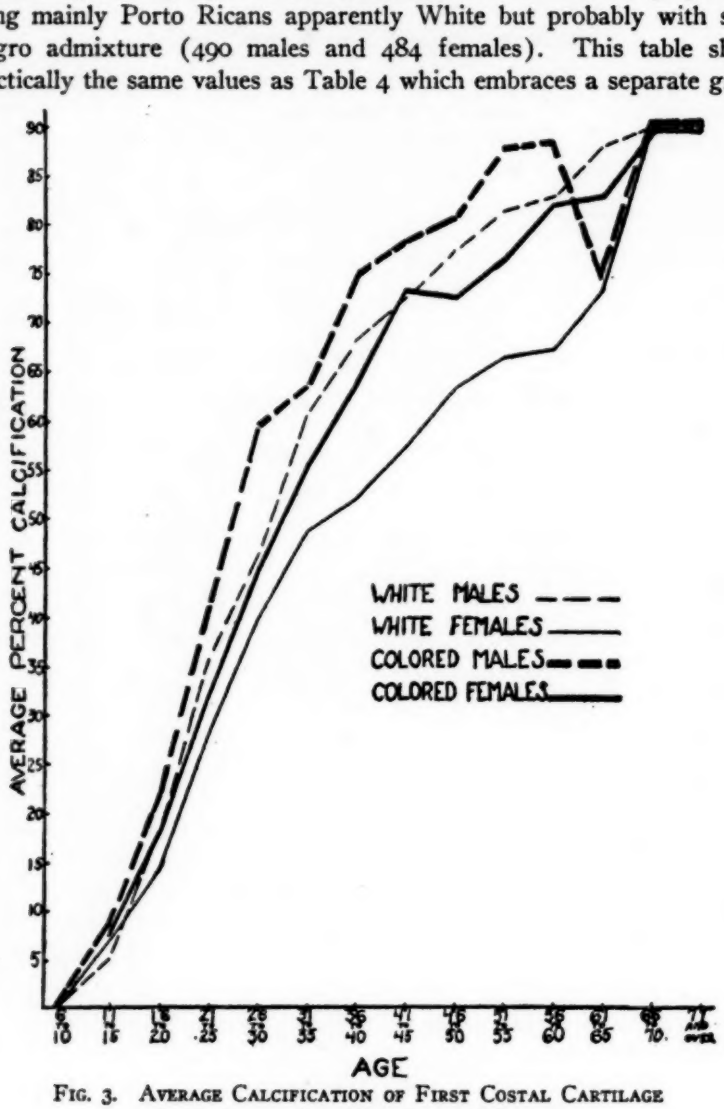


FIG. 3. AVERAGE CALCIFICATION OF FIRST COSTAL CARTILAGE ACCORDING TO AGE, WHITES AND NEGROES

of 1,076 Negroes (413 males and 663 females). The Colored individuals of these two tables are not identical.

Analogous to the Whites the male Negro shows more calcification than the Negress of equal age. The cartilages of Negroes of both sexes calcify more rapidly than those of the Whites. This is apparent even in adolescence and holds true for all the age groups. Despite this quantitative racial difference the most rapid increase of average calcification occurs among Negroes around the twentieth year as among Whites. Figure 3 shows graphically the rhythm of average calcification with the increase of age. The data on the mixed population were omitted in the figure since they coincide with the curves obtained from the Negroes.

The cause of the differences in amount of calcification in the two racial groups remains an open question. The same pertains to the factor responsible for the more rapid calcification among the males. It belongs to the realm of conjecture whether the more active thoracic breathing of the female is directly or indirectly linked with a lesser degree of calcification of the costal cartilage. Nor are we prepared to say whether the poorer economic condition of the Colored may have something to do with a more pronounced calcification.

SUMMARY

Thoracic roentgenograms of 5,098 healthy individuals were studied with the object of determining the increase of calcification in the first costal cartilage with the progress of years. Two racial groups were studied: Whites and Negroes. Among both calcification of the first costal cartilage does not start before the eleventh year of age, as a rule. Among both calcification proceeds from the rib toward the sternum. There are hardly any differences noticeable between males and females in each racial group before the fifteenth year of age. At about sixteen years of age males of both racial groups begin to show more intensive calcification than females, and this quantitative difference continues until the sixty-sixth year when both sexes approach the final stage of calcification. In both racial groups men as well as women show the most rapid increase of average calcification at about their twentieth year. After the fortieth year the tempo of the calcification of the first costal cartilage slows down considerably.

In Negroes the costal cartilage of both sexes calcifies more rapidly than in the corresponding age groups of the Whites. This difference is apparent already in adolescence and holds true for the entire life span.

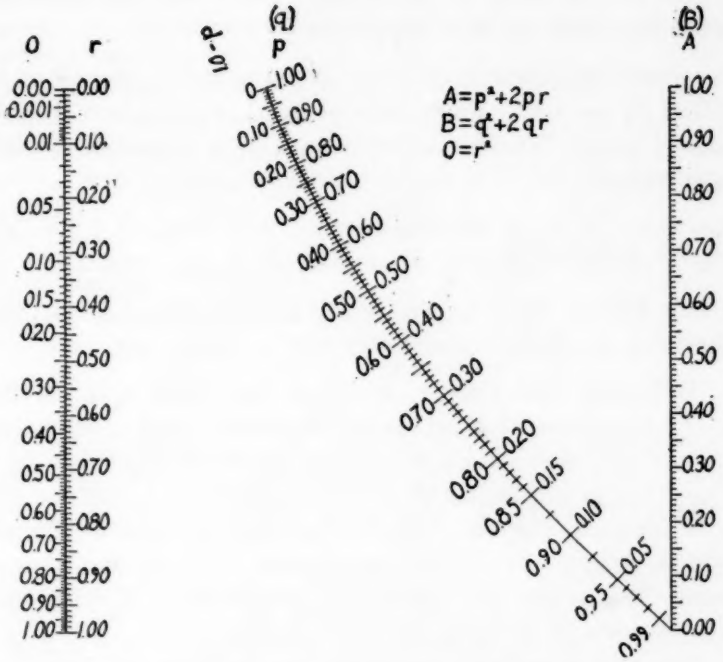
NOTES

NOMOGRAM FOR RAPID COMPUTATION OF THE FREQUENCY OF THE BLOOD GROUPING GENES IN POPULATIONS

WHEN calculating the frequency of the blood grouping genes r, p, and q from the percentages of the blood groups O, A, B, and AB given by the numerous authors for various populations, the present writer has found the attached nomographic or alignment chart useful in avoiding arithmetic labors. The manner of using it may be understood from the following description.

The chart is read by means of a ruler, or stretched thread, between the index lines. A very convenient instrument is a piece of transparent celluloid, such as X-ray film, which has had a scratch ruled on it and filled with India ink. On the left of the chart will be found the scale for group O, and on the right the scale for group A. Suppose group O is 45 per cent, and group A is 42 per cent. Set the ruler across the indices in such a way that it crosses the O scale (on the left side of the left-hand scale) at 0.45 and the A scale (right-hand scale of the chart) at 0.42. Then the value of p (the gene for A) is read off on the right-hand part of the curved scale as 0.26. The value of r (the gene for O) is read off at the same time directly opposite the value of O, on the right-hand part of the left-hand scale, since $O = r^2$. In this case $r = 0.67$. Since $p + q + r = 1$, the value of q (the gene for B) is equal to the sum of p and r subtracted from 1. On the left-hand part of the curved scale are given the figures corresponding to $1 - p$. By mentally subtracting the value of r just found on the left-hand scale one obtains at once the value of q. In this case $q = 0.74 - .67 = .07$. Thus the values of all three genes can be read off by a single setting on the chart.

Since the equation $B = q^2 + 2qr$ is of the same form exactly as the equation $A = p^2 + 2pr$, which the nomogram solves, it is obvious that



NOMOGRAM FOR THE COMPUTATION OF FREQUENCIES OF BLOOD-GROUPING GENES.

the value of q, instead of p, may be read off directly on the curved scale if the setting on the right-hand scale is made to the observed frequency of group B, instead of group A. This gives q directly, but requires one more setting. If the population is in equilibrium and the observed values are accurate, this result will be the same as that obtained above by subtraction. The difference is seldom great, since the above operation is equivalent to solving for p by the equation $p = \sqrt{O + A} - \sqrt{O}$. Wiener (8) has shown that the value of p thus obtained, plus $r = \sqrt{O}$, added to a value of q obtained from the analogous equation $q = \sqrt{O + B} - \sqrt{O}$, gives a result only slightly different from 1, for most populations. It would seem desirable to set on the right-hand scale to the observed value of A or B, according to which is larger (and therefore somewhat more accurate), and obtain the value of the other

gene, q or p respectively, by subtraction. The results for some representative populations are illustrated below.

White Americans (New York) (7). O = 45.6, A = 36.4, B = 13.5, AB = 4.5 per cent. From chart $r = 0.68$, $p = .22$, $q = .10$. Calculated (from Wiener's equations), r, p, q respectively = 0.676, .229, .094.

Buriats (5). O, A, B, AB respectively = 33.3, 20.9, 37.5, 8.3. From chart r, p, $q = 0.58$, .16, .26; calculated = .577, .159, .264.

American Indians (6). O, A, B, AB = 70.8, 28.6, .4, .2. From chart r, p, $q = 0.84$, .15, .01; calculated = 0.839, .157, .006.

It is believed that there is no longer any doubt that the Bernstein (1) hypothesis of blood group inheritance, used here, conforms with the known observations better than any other hypothesis (4, 8). It is also thought that the present chart is rather more convenient to use than the complicated graph of Fischer (2), also based on the Bernstein hypothesis, where interpolation was between curves, and thus less accurate. This graph was printed in a journal which is unfortunately not readily accessible to many American readers.

It remains to be pointed out that the chart could be used for any data for the case of three allelomorphs where two factors are dominant over a third, but not over each other. A little consideration will show that even if the third factor, say X_3, is dominant over the second, X_2, as well as the first, X_1, the chart could still be applied by using data on the classes lacking X_3.

Since the M and N factors of Landsteiner and Levine are inherited as a series of two allelomorphs, neither dominant, the frequency of the genes m and n can be obtained directly by a slide rule, since $m = \sqrt{M + N}$—, etc., but of course the O, r, scale could be used.

The author wishes to express his best thanks to Mr. A. B. Guise, who drew and lettered the chart.

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THE VARIANCE OF A GROUPED FREQUENCY DISTRIBUTION WHEN THE MEAN OF EACH CLASS IS TAKEN AS CENTERING POINT[1]

IN CALCULATING the moments of a grouped frequency distribution the usual procedure is to assume that the frequency in each class is concentrated at the midpoint of the class. This assumption introduces certain errors, to correct for which Sheppard[2] derived his well-known formulae. Sometimes in an endeavor to come closer to the moments which would be obtained from the original ungrouped observations the mean of each class is calculated and the frequency in the class treated as though it were concentrated at the mean. This procedure of course gives the same mean for the distribution as would be obtained from the ungrouped observations but it is apparently often overlooked that the variance and standard deviation are in general less than those calculated from the ungrouped observations. This may easily be proved as follows:

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[1] From the Department of Biology of the School of Hygiene and Public Health of the Johns Hopkins University.

[2] Sheppard, W. F. On the calculation of the most probable values of frequency constants, for data arranged according to equidistant divisions of a scale. *Proc. London Math. Soc.,* Vol. 29, p. 353 *et seq.*

Id. The calculation of moments of a frequency distribution. *Biometrika,* Vol. 5, pp. 450-459, 1906-07.

In the ith class let there be y_{i1} observations having the value X_{i1}, y_{i2} observations having the value X_{i2}, and so on to y_{in_i} observations having the value X_{in_i}. Let $x_{ik} = X_{ik} - M$, where M is the mean of the whole distribution.

Then $(x^2_{ik} - x^2_{il})^2 = x^4_{ik} - 2x^2_{ik}\,x^2_{il} + x^4_{il} \geqslant 0$, since the square of a real number cannot be negative.

Adding $4x^2_{ik}\,x^2_{il}$ to both sides of the inequality,

$$x^4_{ik} + 2x^2_{ik}\,x^2_{il} + x^4_{il} = (x^2_{ik} + x^2_{il})^2 \geqslant 4x^2_{ik}\,x^2_{il}$$

Taking the square root of both sides,

$$x^2_{ik} + x^2_{il} \geqslant 2x_{ik}\,x_{il}$$

Therefore

$$y^2_{i1}\,x^2_{i1} + y^2_{i2}\,x^2_{i2} + \ldots + y^2_{in_i}\,x^2_{in_i} + y_{i1}\,y_{i2}\,(x^2_{i1} + x^2_{i2}) + \ldots + y_{i(n_i-1)}\,y_{in_i}\,(x^2_{i(n_i-1)} + x^2_{in_i}) \geqslant y^2_{i1}\,x^2_{i1} + y^2_{i2}\,x^2_{i2} + \ldots + y^2_{in_i}\,x^2_{in_i} + 2y_{i1}\,y_{i2}\,x_{i1}\,x_{i2} + \ldots + 2y_{i(n_i-1)}\,y_{in_i}\,x_{i(n_i-1)}\,x_{in_i}$$

Therefore

$$(y_{i1} + y_{i2} + \ldots + y_{in_i})\,(y_{i1}\,x^2_{i1} + y_{i2}\,x^2_{i2} + \ldots + y_{in_i}\,x^2_{in_i}) \geqslant (y_{i1}\,x_{i1} + y_{i2}\,x_{i2} + \ldots + y_{in_i}\,x_{in_i})^2$$

But $y_{i1}\,x_{i1} + y_{i2}\,x_{i2} + \ldots + y_{in_i}\,x_{in_i} = (y_{i1} + y_{i2} + \ldots + y_{in_i})\,m_i$, where m_i is the mean of the ith class. Therefore

$$(y_{i1}\,x^2_{i1} + y_{i2}\,x^2_{i2} + \ldots + y_{in_i}\,x^2_{in_i}) \geqslant (y_{i1} + y_{i2} + \ldots + y_{in_i})\,m^2_i$$

If there are t classes

$$\frac{\sum_{i=1}^{t} (y_{i1}x^2_{i1} + y_{i2}x^2_{i2} + \ldots + y_{in_i}x^2_{in_i})}{\sum_{i=1}^{t} (y_{i1} + y_{i2} + \ldots + y_{in_i})} \geqslant \frac{\sum_{i=1}^{t} (y_{i1} + y_{i2} + \ldots + y_{in_i})m^2_i}{\sum_{i=1}^{t} (y_{i1} + y_{i2} + \ldots + y_{in_i})}$$

But the left side of this inequality is the variance calculated from the ungrouped observations, while the right side is the variance calculated on the assumption that the frequency in each class is concentrated at the mean of the class. The two variances are equal only in the case where all the observations in the ith class ($i = 1, 2, \ldots, t$) have the same value.

As an arithmetical illustration I took the greatest length from glabella to occiput (L) of the first 25 male skulls given in the folding tables at the end of Macdonell's [3] study of the Whitechapel crania. The mean of the ungrouped observations is 189.28 mm. and the standard deviation 5.36 mm. I then grouped the observations into six classes of 5 mm. interval. As would be expected for cranial measurements the distribution is approximately symmetrical with high contact at both ends. When the centering point is taken at the midpoint of each class the mean is 189.60 mm. and the standard deviation without Sheppard's correction is 5.68 mm. With Sheppard's correction the standard deviation is 5.49 mm. When the centering point is taken at the mean of each class the mean of the distribution is of course the same as that of the ungrouped observations and the standard deviation is 5.31 mm., or less than the standard deviation from the ungrouped observations.

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In this department will be noticed the books and reprints which are currently received at the Editorial Office. Publications intended for notice here should be addressed to Dr. Raymond Pearl, Department of Biology, School of Hygiene and Public Health, 1901 East Madison Street, Baltimore, Maryland, U. S. A.

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